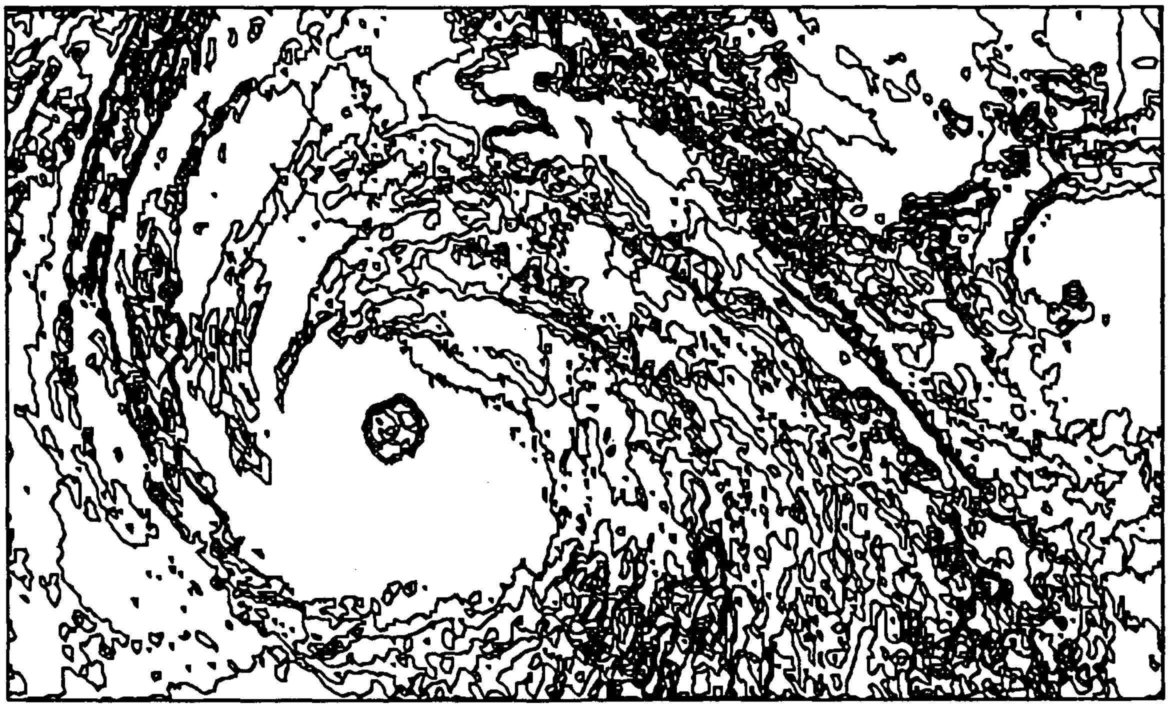
(1)

1988 ANNUAL TROPICAL CYCLONE REPORT



JOINT TYPHOON WARNING CENTER
GUAM, MARIANA ISLANDS

FRONT COVER: Contouring of visual satellite imagery enhances the cloud topography of Typhoon Hal (14W) with its large ragged eye and (at the right edge of the picture) the comma shape of Tropical Storm Irma (15W). These two tropical cyclones were active with Tropical Storm Jeff (16W) and Typhoon Uleki (01C) during the second week of September.

U. S. NAVAL OCEANOGRAPHY COMMAND CENTER
JOINT TYPHOON WARNING CENTER
COMNAVMARIANAS BOX 17
FPO SAN FRANCISCO, CA 96630

ROBERT J. PLANTE

CAPTAIN, UNITED STATES NAVY
COMMANDING OFFICER

DANIEL J. McMORROW

LIEUTENANT COLONEL, UNITED STATES AIR FORCE
DIRECTOR, JOINT TYPHOON WARNING CENTER
COMMANDER, DETACHMENT 1, 1ST WEATHER WING

STAFF

JOINT TYPHOON WARNING CENTER

*	LCDR	GEORGE M. DUNNAVAN	USN
	LCDR	JOHN L. HEISHMAN	USN
*	LCDR	BRIAN J. WILLIAMS	USN
*	CAPT	STEVEN B. DREKSLER	USAF
	LT	RICHARD H. BOUCHARD	USN
	CAPT	ROBERT F. CROSBY	USAF
	LT	RYAN R. SCHULTZ	USN
*	LT	STEVE J. FATJO	USN
	CAPT	JOHN M. ROGERS	USAF
	CAPT	JOHN D. PICKLE	USAF
**	LT(JG)	STACY R. STEWART	USNR-R
	1LT	ROBERT J. FALVEY	USAF
	ENS	RICHARD L. JEFFRIES	USN
*	AG2	RAYMOND L. BROOKS	USN
	SSGT	DONALD L. NOVAK, JR.	USAF
	AG2	BARRY F. BROCKMAN	USN
*	SSGT	MICHAEL P. STEELE	USAF
*	AG3	DEANNA L. WILHITE	USN
*	AG3	SHIRLEY A. MURDOCK	USN
	SGT	ANGELIA C. BLAISDELL	USAF
	SGT	JAMES B. WIEMANN	USAF
*	AG3	SEAN L. KLOPE	USN
	SGT	JAMES B. BUNKER	USAF
	SRA	DONALD L. MILLER	USAF
	AG3	JEFFERY L. CHAPIN	USN
	AG3	KIMBERLEY J. WOODS	USN
	AGAN	AVERY G. DUNCAN	USN
	AGAN	JEREMY D. WILLIAMS	USN

DET 1, 1WW SATELLITE OPERATIONS

	MAJ	JOEL D. MARTIN	USAF
*	CAPT	DAN B. MUNDELL	USAF
*	CAPT	KENNETH W. REESE	USAF
	1LT	TIM D. HUTCHISON	USAF
	MSGT	ROBERT E. REDINGER	USAF
	MSGT	CHARLES J. BONINI	USAF
*	MSGT	JEFFERY L. FLEMING	USAF
	TSGT	TONI D. HUMPHREY	USAF
*	TSGT	ALAN W. ROBB	USAF
	SSGT	ROBERT C. GRAY	USAF
	SSGT	JACK L. WILSON	USAF
	SSGT	WAYNE I. GENTRY	USAF
	SSGT	PAUL F. HARPER	USAF

EDITORS

LT	DOUGLAS H. SCOVIL, JR.	USN
MR	FRANK H. WELLS	CIV

* TRANSFERRED DURING 1988
** ON ACTIVE DUTY TRAINING WITH JTWC

DISTRIBUTION LIST

1 COPY
BRUNEI SHELL PETROLEUM CO
BUREAU OF METEOROLOGY RESEARCH CENTER
CATHOLIC UNIVERSITY OF AMERICA
CENTRAL MET OBSERVATORY, BEIJING
CENTRAL METEOROLOGICAL OFFICE, SEOUL
CHULALONGKORN UNIVERSITY, BANGKOK
CHUNG CHENG INSTITUTE, TAIWAN
CITIES SERVICES OIL GAS CORP
CIUDAD UNIVERSITARIA, MEXICO
CIVIL DEFENSE, SAIPAN
CINCPACFLT
CNO (OP-096)
CNO (OP-096T)
CNO (OP-981D)
CNO (OP-943G)
COLORADO STATE UNIVERSITY LIBRARY
COMNAVOCEANCOM
COMNAVSURFGRU WESTPAC
COMNAVSURFPAC
COMPHIBGRU ONE
COMSC
COMSEVENTHFLT
COMSUBGRU SEVEN
COMTHIRDFLT
CONGRESSIONAL INFORMATION SERVICE, MD
DCA GUAM
DET 2, 20 WS
DET 4, 20 WS
DET 5, 20 WS
DET 8, 20 WS
DET 10, 30 WS
DET 13, 20 WS/CC
DET 15, 30 WS
DET 17, 20 WS
DISASTER CONTROL OFFICE, SAIPAN
ECMWF, BERKSHIRE, UK
FAIRECONRON ONE
FOREST DIVISION, JMA
GEOLOGICAL FLUID DYNAMICS LAB, PRINCETON, NJ
GEOLOGICAL SURVEY, GUAM
GODDARD SPACE FLIGHT CENTER
GUAM PUBLIC LIBRARY
HQ AWS/DN
HQ MAC/DOOS
HQ USAF/XOORZ
HUGHES AIRCRAFT CO
INSTITUO DE GEOFISICA, MEXICO
JCS ENV SERVICES DIV (J3(OES))
LOS ANGELES PUBLIC LIBRARY
MASS INST OF TECH
MCAS KANEOHE BAY HI
METEOROLOGY DEPT, BANGKOK
MOBIL OIL GUAM INC
MOUNTAIN STATES WEATHER SERVICES
NATIONAL TAIWAN UNIVERSITY
NAVAL CIVIL ENG LAB, PORT HUENEME, CA
NAVDEP NOAA
NAVEASTOCEANCEN NORFOLK
NAVHISTCEN
NAVOCEANCOMCEN ROTA
NAVOCEANCOMDET AGANA
NAVOCEANCOMDET ALAMEDA
NAVOCEANCOMDET ASHEVILLE
NAVOCEANCOMDET ATSUGI
NAVOCEANCOMDET BARBERS POINT
NAVOCEANCOMDET KADENA
NAVOCEANCOMDET MONTEREY
NAVOCEANCOMFAC YOKOSUKA
NAVPGSCOL LIBRARY
NAVPOLAROCEANCEN SUITLAND
NAVAL RESEARCH LAB
NOAA/ACQUISITION SECTION, ROCKVILLE, MD
NOAA/AOML, HRD, MIAMI, FL
NOAA/HYDROMETEOROLOGY BR, SILVER SPRINGS, MD
NOAA/NESDIS, REDWOOD CITY, CA
NOAA/PMEL, SEATTLE, WA
NOAA LIBRARY, MIAMI, FL
NOBEL DENTON
OCEAN ROUTES INC, CA
OCEANO SERVICES INC. LIBRARY
OCEANWEATHER, INC.
OFFICE OF NAVAL RESEARCH
PACIFIC STARS & STRIPES
PACNAVFACENGCOM
PENNSYLVANIA STATE UNIVERSITY
SRI LIBRARY
TEXAS A & M UNIVERSITY
UNIVERSITY OF CHICAGO
UNIVERSITY OF GUAM, BIOLOGY DEPT
UNIVERSITY OF HAWAII (LIBRARY)
UNIVERSITY OF WASHINGTON
USCINCPAC
USCINCPAC REP GUAM
USCINCPAC REP PHILIPPINES
USNA (OCEANOGRAPHY DEPT/LIBRARY)
USS AMERICA (CV 66)
USS BELLEAU WOOD (LHA 3)
USS CARL VINSON (CVN 70)
USS CONSTELLATION (CV 64)
USS CORAL SEA (CV 43)
USS EISENHOWER (CVN 69)
USS ENTERPRISE (CVN 65)
USS FORRESTAL (CV 59)
USS INDEPENDENCE (CV 62)
USS IOWA (BB 61)
USS J. F. KENNEDY (CV 67)
USS KITTY HAWK (CV 63)
USS LINCOLN (CVN 72)
USS MIDWAY (CV 41)
USS MISSOURI (BB 63)
USS NEW JERSEY (BB 62)
USS NEW ORLEANS (LPH 11)
USS NIMITZ (CVN 68)
USS OKINAWA (LPH 3)
USS PELELIU (LHA 5)
USS RANGER (CV 61)
USS SARATOGA (CV 60)
USS TARAWA (LHA 1)
USS TRIPOLI (LPH 10)
USS T. ROOSEVELT (CVN 71)
USS WISCONSIN (BB 64)
WORLD DATA CENTER B1, MOSCOW
WORLD WEATHER BUILDING, MD

3AD/DO
3WW/CC
3WW/DN
7WW/OL-A
20 WS/DO
30WS/DO
34 AWF, 920 WRG
43 SW/DO
3350 TCHTG/TTMV-S

2 COPIES
AFGWC/WFMP
AWS/DOOF
BUREAU OF METEOROLOGY, BRISBANE
BUREAU OF METEOROLOGY, DARWIN
BUREAU OF METEOROLOGY, PERTH
BUREAU OF PLANNING, GUAM
DEPARTMENT OF COMMERCE
ESCAP LIBRARY, BANGKOK
FLENUMOCEANCEN MONTEREY
FLORIDA STATE UNIVERSITY
HQ AWS/DOR
HQ AWS GP, JAPAN
INSTITUTE OF PHYSICS, TAIWAN
MARATHON OIL CO, TX
MARINERS WEATHER LOG
MCAS FUTENMA
MET RESEARCH INST LIBRARY, TOKYO
METEOROLOGY SOCIETY OF NEW SOUTH WALES, AUST
MICRONESIAN RESEARCH CENTER UOG, GUAM
NATIONAL CLIMATIC DATA CENTER
NATIONAL METEOROLOGICAL LIBRARY, BRACKNELL, UK
NATIONAL WEATHER OFFICE, PAGASA
NATIONAL WEATHER SERVICE, HONOLULU
NAVOCEANCOMDET DIEGO GARCIA
NAVOCEANCOMDET MISAWA
NAVOCEANCOMFAC CUBI PT
NAVOCEAN COMFAC JACKSONVILLE
NAVWESTOCEANCEN PEARL HARBOR
NOAA CORAL GABLES LIBRARY
NOAA GUAM
OKINAWA METEOROLOGY OBSERVATORY
PACAF/DOW
SAT APPL LAB, NOAA/NESDID, CAMP SPRINGS, MD
SAT APPL LAB, NOAA/NESDIS, REDWOOD CITY, CA
TYPHOON COM SECR, MANILA
UNIVERSITY OF PHILIPPINES
US ARMY, FORT SHAFTER
WORLD DATA CENTER A, NOAA
17 WS/DON
23 AF/HQ
73 WEATHER GROUP, ROK AF

3 COPIES
AWS TECH LIBRARY
BUREAU OF METEOROLOGY, MELBOURNE
CENTRAL WEATHER BUREAU, TAIWAN
HQ AWS/DN
INDIA METEOROLOGICAL DEPT
INOSHAC, DDGM (WF)
JAPAN METEOROLOGY AGENCY
MCAS IWAKUNI
NATIONAL HURRICANE CENTER, MIAMI
NAVPGSCOL DEPT OF METEOROLOGY
UNIVERSITY OF HAWAII, METEOROLOGY DEPT
1WW/DN

4 COPIES
COLORADO STATE UNIVERSITY
METEOROLOGY DEPT, BANGKOK
NATIONAL WEATHER ASSOCIATION
5WW/CC

5 COPIES
CIVIL DEFENSE, GUAM
PAGASA WEATHER BUREAU, RP
R & D UNIT, NHC, MIAMI
ROYAL OBSERVATORY HONG KONG

6 COPIES
NEPRF

12 COPIES
DEFENSE TECHNICAL INFORMATION CENTER

FOREWARD

The Annual Tropical Cyclone Report is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined Air Force/Navy organization operating under the command of the Commanding Officer, U.S. Naval Oceanography Command Center/Joint Typhoon Warning Center, Guam. JTWC was established in April 1959 when USCINCPAC directed USCINCPACFLT to provide a single tropical cyclone warning center for the western North Pacific region. The operations of JTWC are guided by CINCPACINST 3140.1S.

The mission of the Joint Typhoon Warning Center is multi-faceted and includes:

1. Continuous monitoring of all tropical weather activity in the northern and southern hemispheres, from 180 degrees longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuing warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of reconnaissance requirements for tropical cyclone surveillance and assignment of appropriate priorities.

4. Post-storm analysis of all significant tropical cyclones occurring within the western North Pacific and North Indian Oceans, which includes an in-depth analysis of tropical cyclones of note and all typhoons.

5. Cooperation with the Naval Environmental Prediction Research Facility (NEPRF), Monterey, California, on the operational evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support operational forecast scenarios.

Satellite imagery used throughout this report represents data obtained by the DMSP network. The personnel of Detachment 1, 1WW, collocated with JTWC at Nimitz Hill, Guam, coordinate the satellite acquisitions and tropical cyclone reconnaissance with the following units:

Det 4, 20WS, Hickam AFB, Hawaii

Det 5, 20WS, Clark AB, Republic of the Philippines

Det 8, 20WS, Kadena AB, Japan

Det 15, 30WS, Osan AB, Korea

Air Force Global Weather Central, Offutt AFB, Nebraska

In addition, the Naval Oceanography Command Detachment, Diego Garcia, and Defense Meteorological Satellite Program (DMSP) equipped U.S. Navy ships have been instrumental in providing vital fixes of tropical cyclones in the Indian Ocean from satellite data.

Should JTWC become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC) located at the U.S. Naval Western Oceanography Center, Pearl Harbor, Hawaii, assumes warning responsibilities. Assistance in determining satellite reconnaissance requirements, and in obtaining the resultant data, is provided by Det 4, 20WS Hickam AFB, Hawaii.

Special thanks to: Navy Captain Carl W. Hoffman for his significant contributions and support; the men and women of the 27th Communications Squadron, Operating Location Charlie and the Operations department of the Naval Oceanography Command Center, Guam for their continuing support by providing high quality real-time satellite imagery; Marine Corps Air Station, Futenma, Japan for sharing their satellite imagery of STY Nelson (20W); the Pacific Fleet Audio-Visual Center, Guam for their assistance in the reproduction of satellite data for this report; to the Navy Publications and Printing Service Branch Office, Guam; the Royal Observatory Hong Kong for supporting synoptic data on TS Mamie (19W) and TY Ruby (23W); Dr. Bob Abbey and the Office of Naval Research for their technical support to this publication and support to the University of Hawaii for the Post Doctorate Fellow at JTWC; Dr. Mark Lander for his training efforts, suggestions and detailed work on CSUM; Dr. Greg Holland for his work with Major Joel Martin to develop a more representative periphery wind technique; the Australian Meteorological Service for the coastal radar reports on tropical cyclones via the AFTN to JTWC; Mr. Andy Chun and the CPHC for the data package on TY Uleki (01C); the Royal Navy and Royal Observatory Hong Kong for making possible the liaison visit by Lt. Cmdr. David Gray; National Weather Service Pacific Region for the startup of 24-hour operations at Ponape, Truk, Majuro and Koror, the retrieval of the HANDAR observations from their computer in Hawaii for TY Roy (01W), and Mr. Tom Yoshida for the development of the Tropical Cyclone Reporting Form for post-storm support to JTWC; First Weather Wing for expediting the delivery of the Alden receiver for PACDIGS; and the Federated States of Micronesia for endorsing the AMOS installation on Faraulep Atoll.

Note: Appendix IV contains information on how to obtain past issues of the Annual Tropical Cyclone Report (titled Annual Typhoon Report prior to 1980).

TABLE OF CONTENTS

CHAPTER I OPERATIONAL PROCEDURES PAGE

1. General 1
2. Data Sources. 1
3. Communications. 4
4. Data Displays. 5
5. Analyses 5
6. Forecast Aids. 6
7. Forecast Procedures. 6
8. Warnings. 7
9. Prognostic Reasoning Messages 8
10. Tropical Cyclone Formation Alerts. 8
11. Significant Tropical Weather Advisories. 8

CHAPTER II RECONNAISSANCE AND FIXES

1. General 9
2. Reconnaissance Availability 9
3. Aircraft Reconnaissance Summary 9
4. Satellite Reconnaissance Summary 10
5. Radar Reconnaissance Summary 13
6. Tropical Cyclone Fix Data 13

CHAPTER III SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

1. General 17
2. Western North Pacific Tropical Cyclones 22

INDIVIDUAL TROPICAL CYCLONES

TROPICAL CYCLONE	AUTHOR	PAGE	TROPICAL CYCLONE	AUTHOR	PAGE
(01W) TY ROY	REESE	28	(14W) TY HAL	FALVEY	84
(02W) TY SUSAN	DREKSLER	36	(01C) TY ULEKI	ROGERS/SCOVIL	88
(03W) TD 03W	PICKLE	40	(15W) TS IRMA	CROSBY	93
(04W) TY THAD	SCOVIL	44	(16W) TS JEFF	PICKLE	94
(05W) TS VANESSA	SCHULTZ	48	(17W) TS KIT	SCOVIL	100
(06W) TY WARREN	BOUCHARD	52	(18W) TS LEE	SCHULTZ	104
(07W) TS AGNES	FALVEY	56	(19W) TS MAMIE	BOUCHARD	108
(08W) TS BILL	ROGERS	60	(20W) STY NELSON	FALVEY	112
(09W) TS CLARA	CROSBY	66	(21W) TY ODESSA	ROGERS	118
(10W) TY DOYLE	PICKLE	70	(22W) TY PAT	CROSBY	122
(11W) TS ELSIE	SCOVIL	75	(23W) TY RUBY	PICKLE	126
(12W) TY FABIAN	SCHULTZ	76	(24W) TY SKIP	SCOVIL	130
(13W) TS GAY	BOUCHARD	82	(25W) TY TESS	SCHULTZ	134
			(26W) TS VAL	JEFFRIES/SCHULTZ	138

3. North Indian Ocean Tropical Cyclones 142
4. North Indian Ocean Climatology 143

INDIVIDUAL TROPICAL CYCLONES

TROPICAL CYCLONE	AUTHOR	PAGE
TC 01A	ROGERS	146
TC 02B	BOUCHARD	150
TC 03B	SCHULTZ	152
TC 04B	PICKLE	154
TC 05B	SCOVIL	158

CHAPTER IV SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES
1. General 161
2. South Pacific and South Indian Ocean Tropical Cyclones 161

CHAPTER V SUMMARY OF FORECAST VERIFICATION
1. Annual Forecast Verification 169
2. Comparison of Objective Techniques 182

CHAPTER VI TROPICAL CYCLONE SUPPORT SUMMARY
1. Naval Environmental Prediction Research Facility 189

ANNEX A TROPICAL CYCLONE TRACK AND FIX DATA
1. General 191
2. Warning Verification Statistics 191

APPENDICES I. Definitions 212

II. Names for Tropical Cyclones 213

III. References 214

IV. Past Annual Tropical Cyclone Reports 216

CONTRACTIONS

ABIO	Significant Tropical Weather Advisory for the Indian Ocean
ABPW	Significant Tropical Weather Advisory for the Western Pacific Ocean
ACFT	Aircraft
ADP	Automated Data Processing
AFGWC	Air Force Global Weather Central
AIREP	Aircraft (Weather) Report (Commercial and Military)
AMOS	Automatic Meteorological Observing Station
AOR	Area of Responsibility
APT	Automatic Picture Transmission
ARGOS	International Service for Drifting Buoys
ATCF	Automated Tropical Cyclone Forecast System
ATCM	Advanced Tropical Cyclone Model
AUTODIN	Automated Digital Network
AWDS	Automated Weather Distribution System
AWN	Automated Weather Network
BT LAT	Best Track Latitude
BT LON	Best Track Longitude
BT WN	Best Track Wind
CDO	Central Dense Overcast
CI	Cirriform Cloud or Cirrus (or) Current Intensity (Dvorak)
CINCPAC	Commander-in-Chief Pacific AF - Air Force, FLT - Navy
CLD	Cloud
CLIM	Climatology
CLIPER	Climatology and Persistence Technique
CM	Centimeter
CNOC	Commander Naval Oceanography Command
COSMOS	Cyclops Objective Steering Model Output Statistics
CPA	Closest Point of Approach
CPHC	Central Pacific Hurricane Center
CSC	Cloud System Center
CSUM	Colorado State University (CSU84) Model
CYCLOPS	Tropical Cyclone Steering Program (HATTRACK and MOHATT)
DDN	Defense Data Network
DEG	Degree
DFS	Digital Facsimile System
DMSP	Defense Meteorological Satellite Program
DSAT	Digital Satellite Acquitition System
DSN	Defense Switched Network
DTG	Date Time Group
DWIPS	Digital Weather Image Processing System
FI	Forecast Intensity (Dvorak)
FNOC	Fleet Numerical Oceanography Center
FT	Feet
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
HATTRACK	Hurricane and Typhoon Tracking and Steering Program
HPAC	Mean of XTRP and CLIM Techniques (Half Persistence and Climatology)
HR(S)	Hour(s)
ICAO	International Civil Aviation Organization
INIT	Initial
INJAH	North Indian Ocean Component of TYAN
INST	Instruction
IR	Infrared
JTWC	Joint Typhoon Warning Center
JTWC-AP	Joint Typhoon Warning Center Automation Project
KM	Kilometer(s)
KT	Knot(s)
LAN	Local Area Network
LLCC	Low-Level Circulation Center
LVL	Level
M	Meter(s)
MAX	Maximum
MB	Millibar(s)
MDUS	Medium-scale Data Utilization System
MDUS-R	Medium-scale Data Utilization System Replacement
MET	Meteorological
MIN	Minimum
MOHATT	Modified HATTRACK
MOVG	Moving
MSLP	Minimum Sea-level Pressure
NARDAC	Naval Regional Data Automation Center

NEDN	Naval Environmental Data Network
NEDS	Naval Environmental Display Station
NEPRF	Naval Environmental Prediction Research Facility
NESDIS	National Environmental Satellite, Data, and Information Service
NM	Nautical Mile(s)
NOAA	National Oceanic and Atmospheric Administration
NOCC	Naval Oceanography Command Center
NODDES	Naval Environmental Data Network Oceanographic Data Distribution and Expansion System
NODDS	Navy/NOAA Oceanographic Data Distribution System
NOGAPS	Navy Operational Global Atmospheric Prediction System
NORAPS	Navy Operational Regional Atmospheric Prediction System
NSDS	Naval Satellite Display System
NWOC	Naval Western Oceanography Center
NWS	National Weather Service
NR	Number
NRL	Naval Research Laboratory
OBS	Observations
ONR	Office of Naval Research
OTCM	One Way (Interactive) Tropical Cyclone Model
PACDIGS	Pacific Digital Information Graphics System
PACMEDS	Pacific Meteorological Data System
PACOM	Pacific Command
PCN	Position Code Number
PIREP	Pilot Weather Report(s)
POS ER	(Initial) Position Error
RADOB	Radar Observation
RECON	Reconnaissance
RRDB	Reference Roster Data Base
RSDB	Raw Satellite Data Base
SAT	Satellite
SEC	Second
SDHS	Satellite Data Handling System
SFC	Surface
SGDB	Satellite Global Data Base
SLP	Sea-Level Pressure
SRP	Selective Reconnaissance Program
SST	Sea Surface Temperature
STNRY	Stationary
ST	Subtropical
STR	Subtropical Ridge
STY	Super Typhoon
TAPT	Typhoon Acceleration Prediction Technique
TC	Tropical Cyclone
TCFA	Tropical Cyclone Formation Alert
TD	Tropical Depression
TDA	Typhoon Duty Assistant
TDO	Typhoon Duty Officer
TIROS	Television Infrared Observational Satellite
TOGA	Tropical Ocean Global Atmosphere
TS	Tropical Storm
TUTT	Tropical Upper-Tropospheric Trough
TY	Typhoon
TYAN	Typhoon Analog (Program)
TYFN	Western North Pacific Component (Revised) of TYAN
TYMNET	Time-Sharing Network: Commercial wide area network connecting micro- and mainframe computers
ULAC	Upper-Level Anticyclone
ULCC	Upper-Level Circulation Center
USAF	United States Air Force
USN	United States Navy
VIS	Visual
WESTPAC	Western (North) Pacific
WMO	World Meteorology Organization
WRNG(S)	Warning(s)
WW ER	Wind Warning Error
W#	Warning Number
XTRP	Extrapolation
Z	Zulu Time (Greenwich Mean Time)
24 ER	24-Hour (Position) Error
48 ER	48-Hour (Position) Error
72 ER	72-Hour (Position) Error
24 WE	24-Hour Wind (Warning) Error
48 WE	48-Hour Wind (Warning) Error
72 WE	72-Hour Wind (Warning) Error

Intentionally left blank.

CHAPTER I - OPERATIONAL PROCEDURES

1. GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine services to the organizations within its area of responsibility, including:

a. SIGNIFICANT TROPICAL WEATHER ADVISORIES

Issued daily, these products describe all tropical disturbances and assess their potential for further development during the advisory period.

b. TROPICAL CYCLONE FORMATION ALERTS

Issued when synoptic or satellite data indicate development of a significant tropical cyclone, in a specified area, is likely.

c. TROPICAL CYCLONE WARNINGS

Issued periodically throughout each day, for significant tropical cyclones, giving forecasts of position and intensity of the system.

d. PROGNOSTIC REASONING MESSAGES

Issued with each warning for tropical depressions, tropical storms, typhoons and super typhoons in the western North Pacific; these messages discuss the rationale behind the most recent JTWC warnings.

JTWC's customers determine the content of JTWC's products according to their changing requirements. Therefore, the spectrum of routine services is subject to change from year to year. Such changes are usually the result of deliberations held at the Annual Tropical Cyclone Conference.

2. DATA SOURCES

a. COMPUTER PRODUCTS

A standard array of numerical and statistical guidance are available from the USN Fleet Numerical Oceanography Center (FNOC) at Monterey, California. FNOC products are received through the Naval Environmental Data Network (NEDN), the Naval Environmental Satellite Network (NESN) and by microcomputers connected to mainframe computers via military and commercial telephone lines.

b. CONVENTIONAL DATA

This data set is comprised of land-based, ship surface and upper-air observations recorded at, or within six hours of, synoptic times. It incorporates cloud-motion winds derived twice a day from satellite imagery and commercial and military Aircraft Reports (AIREPS) of enroute meteorological observations, within six hours of synoptic times. There has been an effort to increase the frequency and use of AIREPS to describe the synoptic situation in otherwise data sparse regions. Additional conventional data sources include three Automated Meteorological Observing Station (AMOS) sites on the islands of Saipan and Rota in the Mariana Islands, and Faraulep in the Caroline Islands. The conventional data is hand plotted and analyzed in the tropics for the surface/gradient and 200 mb levels. These analyses are prepared twice daily from 0000Z and 1200Z synoptic data. Also, FNOC supplies JTWC with computer streamline analyses and prognoses at the 925 mb, 850 mb, 700 mb, 500 mb, 400 mb, 250 mb and 200 mb levels from 0000Z and 1200Z synoptic data.

c. AIRCRAFT RECONNAISSANCE

Aircraft of opportunity are a valuable for providing meteorological data at flight level around the periphery of tropical cyclones and in describing the environment away from tropical cyclones that frequently affect tropical cyclone motion. With their airborne radar, they can remotely sense the inner rainbands and core of the tropical cyclone. Flight safety considerations preclude the use of transient aircraft for tropical cyclone penetration.

d. SATELLITE RECONNAISSANCE

Meteorological satellite imagery recorded at USAF/USN ground sites and USN ships supply day and night coverage in JTWC's area of responsibility. Interpretation of these satellite data provide tropical cyclone positions and estimates of current and forecast intensities (Dvorak, 1984).

e. RADAR RECONNAISSANCE

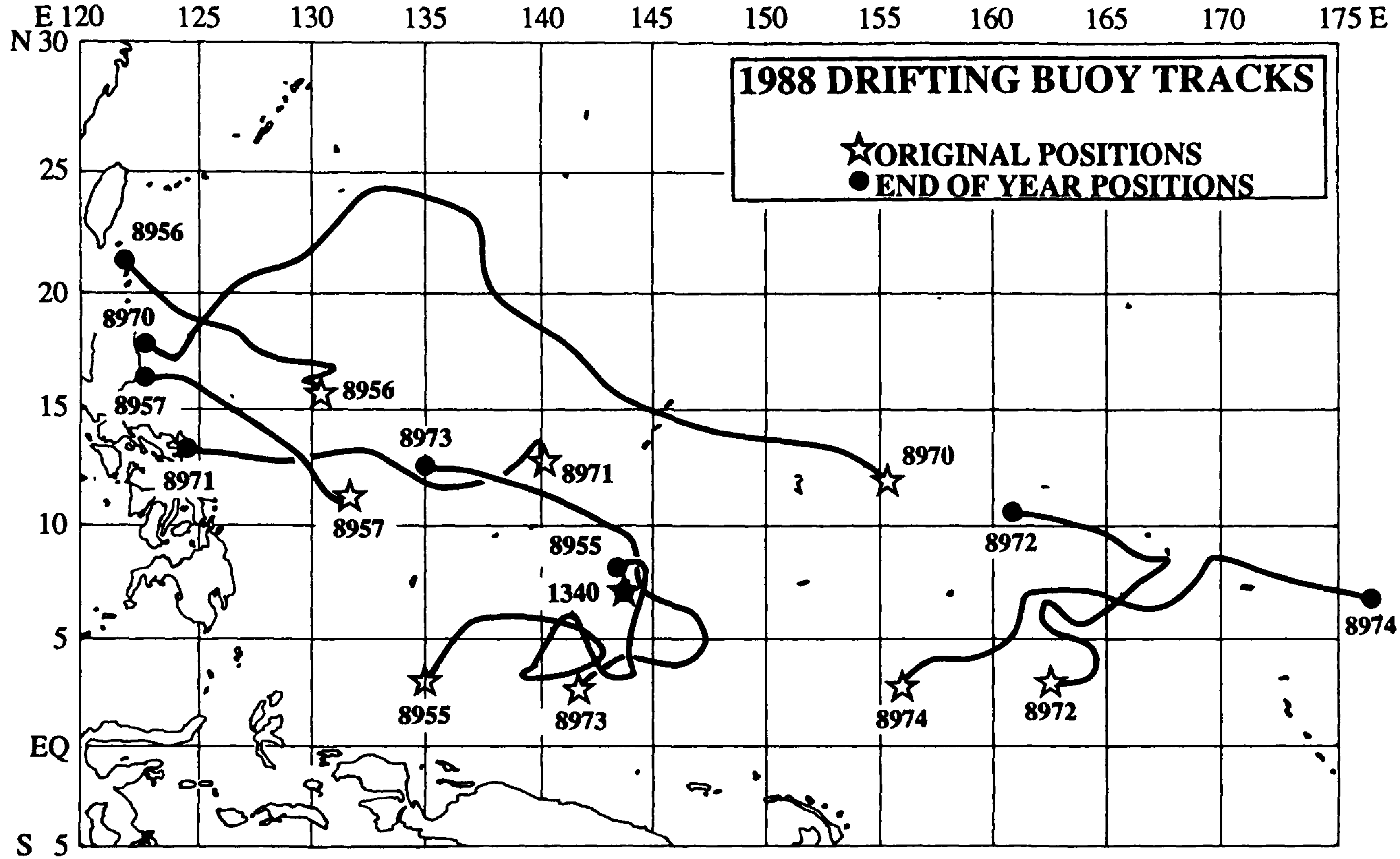
During 1988, as in previous years, land-based radar coverage was utilized extensively, when available. Once a tropical cyclone moved within the range of land-based radar sites, their reports were essential for determination of small-scale movement. Use of radar reports during 1988 is discussed in Chapter II.

f. DRIFTING METEOROLOGICAL BUOYS

In July 1988, nine drifting meteorological buoys were deployed in the western North Pacific to increase the availability of synoptic data, in an often data sparse region. The Naval Oceanography Command provided the funds for procurement and deployment of the buoys and data acquisition equipment. The Naval Oceanographic Office, and JTWC, planned and coordinated the buoy deployments. The 21st Tactical Airlift Squadron at Clark Air Base in the Republic of the Philippines deployed the buoys from C-130 aircraft. All of the buoys provided sea-level pressure, air and sea surface temperatures. Six of the Tropical Ocean Global Atmosphere (TOGA) buoys were retrofitted to provide wind speed and direction. Five buoys were deployed at seven-degree longitude intervals along three degrees North latitude, just south of the Caroline Islands. One of these buoys failed to activate on deployment. (Ironically, a buoy from the 1987 deployment remained active, trapped in an atoll near the failed buoy.) Three buoys were deployed in the Philippine Sea, and the remaining buoy was deployed east of Guam.

JTWC acquired the drifting buoy data directly through its Local User Terminal (LUT). The buoys transmit data to the Tiros-N polar orbiting satellites, which in turn store and relay the data to JTWC's LUT. Four to six observations per day are available from each buoy via direct readout. The stored data is dumped to Service ARGOS in Washington, D.C., where it is passed to the National Data Buoy Center (NDBC) for quality control. JTWC receives the data from NDBC via the Automated Weather Network (AWN). The buoys' positioning systems, wind speed, air pressure and temperature sensors provided accurate data. However, the wind direction data on the modified TOGA's were unreliable. JTWC's internal quality control program computed coarse corrections in an attempt to salvage wind directions, but the results were only of marginal use for the manual surface/gradient level streamline analyses.

The buoys furnished data on Super Typhoon Nelson (20W), Typhoons Odessa (21W), Pat (22W) , Ruby (23W), Skip (24W), Tess (25W), and Tropical Storms Lee (18W) and Val (26W). The tracks of the drifting buoys can be seen in Figure 1-1. Three buoys ceased operating after washing ashore in the Philippine Islands during October, November and December. By the end of 1988, five of nine buoys from the 1988 deployment and one buoy from the 1987 deployment remained operational.


1988 DRIFTING BUOY TRACKS
ORIGINAL POSITIONS
END OF YEAR POSITIONS
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 30
25
20
15
10
5
EQ
S 5
8956
8970
8957
8971
8973
8955
1340
8972
8974

3. COMMUNICATIONS

a. AUTOMATED DIGITAL NETWORK (AUTODIN)

AUTODIN is used for dissemination of warnings, alerts and other related bulletins to Department of Defense installations. These messages are relayed for further transmission over Navy Fleet Broadcasts, and Coast Guard CW (continuous wave Morse Code) and voice broadcasts. Inbound message traffic for JTWC is received via AUTODIN addressed to NAVOCEANCOMCEN GQ or DET 1, 1WW NIMITZ HILL GQ.

b. AUTOMATED WEATHER NETWORK (AWN)

The AWN provides weather data over the Pacific Meteorological Data System (PACMEDS). Operational for JTWC in April 1988, the PACMEDS allows Pacific-Theater agencies to receive weather information at 1200 baud, which is an upgrade from the older 75 baud teletype systems, eliminating data backlogs. The system provides the large volume of meteorological reports necessary to satisfy JTWC requirements. Weather bulletins prepared by JTWC are inserted into the AWN circuit through the Nimitz Hill Naval Telecommunications Center (NTCC), which is controlled by the Naval Communications Area Master Station (NAVCAMS) Western Pacific located on Guam.

c. AUTOMATIC VOICE NETWORK (AUTOVON)

AUTOVON is a world-wide general purpose switched voice network for the Department of Defense. The network provides a rapid and ᵗal voice link for JTWC to communicate tropical cyclone information to customers. The AUTOVON telephone number for JTWC is 344-4224.

d. NAVAL ENVIRONMENTAL DATA NETWORK (NEDN)

The NEDN continues to provide processed and raw environmental data from FNOC to JTWC, and is a communication line for requesting and receiving forecast aids via FNOC's mainframe computers.

e. TIME-SHARING NETWORK (TYMNET)

The use of TYMNET through the Automated Tropical Cyclone Forecast (ATCF) system started in 1987 and aided JTWC's shift away from exclusive dependence on the Naval Environmental Display Station (NEDS) for processing and transmission of tropical cyclone forecast aids, and for receiving environmental fields and raw data. The use of the ATCF microcomputers has improved both the speed of handling and the quality control of these data.

f. DEFENSE DATA NETWORK (DDN)

The DDN is a Department of Defense network of communication lines/links to exchange data files. Because the DDN has links, or gateways, to non-military information networks, it has demonstrated an excellent potential for interfacing with the research community. It was used routinely to transmit SSM/I data from AFGWC to JTWC.

g. TELEPHONE FACSIMILE (TELEFAX)

TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or AUTOVON. The TELEFAX is used to disseminate tropical cyclone advisories and warnings to key agencies on Guam and in special situations the other Micronesian Islands. Inbound documents for JTWC are received via commercial telephone at (671) 477-6186. If inbound through AUTOVON, the Guam AUTOVON operator 322-1110 can transfer the call to the commercial number 477-6186.

h. NAVAL ENVIRONMENTAL SATELLITE NETWORK (NESN)

The NESN's primary function is to pass satellite data between FNOC and regional centers. It can provide a limited back-up for the NEDN.

4. DATA DISPLAYS

a. NAVAL ENVIRONMENTAL DISPLAY STATION (NEDS)

The NEDS is the mainstay for producing displays and hard copies of FNOC environmental products. However, it now serves as a backup for the transmission and receipt of FNOC's objective forecast aids and JTWC's weather messages.

b. AUTOMATED TROPICAL CYCLONE FORECAST SYSTEM (ATCF)

Increased usage of microcomputers in the ATCF has shortened the processing time and improved the quality control of weather bulletins; especially the warnings. The ATCF is still a step away from direct interface with NTCC for AWN and AUTODIN message transmissions, but the Joint Typhoon Warning Center Automation Project (JTWC-AP) will make this needed interface a reality.

c. PACIFIC DIGITAL INFORMATION GRAPHICS SYSTEM (PACDIGS)

The PACDIGS is a new communications circuit that was expanded to include JTWC in 1988. Air Force Global Weather Central (AFGWC) at Omaha, Nebraska provides a standard set of numerical products to the PACDIGS circuit.

d. NAVAL SATELLITE DISPLAY SYSTEM (NSDS)

The NSDS functions primarily for display of FNOC stored satellite imagery and can provide limited back up for the NEDN, via the NESN.

5. ANALYSES

A composite surface/gradient-level (3000 ft (914 m)) manual analysis of the JTWC area of responsibility is accomplished daily on the 0000Z and 1200Z conventional data. Analysis of the wind field using streamlines is stressed for tropical and subtropical regions. Analysis of the pressure field outside the tropics is accomplished routinely by the Naval Oceanography Command Center Operations watch team and is used by JTWC in conjunction with their analysis of the tropical wind fields.

A composite upper-tropospheric manual streamline analysis is accomplished daily at 0000Z and 1200Z, utilizing rawinsonde data from 300 mb through 100 mb, winds obtained from satellite-derived cloud motion analysis, and AIREPS (taken plus or minus three hours of chart valid time) at or above 31,000 ft (9,449 m). Wind and height data are used to generate a representative analysis of tropical cyclone outflow patterns, mid-latitude steering currents, and features that may influence tropical cyclone intensity. All charts are hand-plotted in the tropics to provide all available data as soon as possible to the Typhoon Duty Officer (TDO). These charts are augmented by computer-plotted charts for the final analysis.

Computer analyses for the 925, 850, 700, 500, 400, 250 and 200 mb levels are available from the 0000Z and 1200Z data base. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams and pressure-change charts, are also analyzed during periods of significant tropical cyclone activity.

A Hovmöller Trough-and-Ridge Diagram for 500 mb at 40° North and 30° South latitudes for the entire hemisphere is produced daily to provide a quick look at trough and ridge progression with time.

6. FORECAST AIDS

The following objective tropical cyclone forecasting techniques were employed during 1988 (a description of each technique is presented in Chapter V):

a. MOVEMENT

(1) EXTRAPOLATION

(2) CLIMATOLOGY

(3) HPAC (Half Persistence - Half Climatology Blend)

(4) CLIPER (Climatology and Persistence Technique)

(5) COSMOS (Model Output Statistics)

(6) CSUM (Statistical Dynamic Model)

(7) OTCM (Dynamic Model)

(8) TAPT (Empirical)

(9) TYAN78 (Analog)

b. INTENSITY

(1) CLIMATOLOGY

(2) DVORAK (Empirical)

(3) HOLLAND/MARTIN (Empirical)

7. FORECAST PROCEDURES

a. INITIAL POSITIONING

The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received up to one and one-half hours after synoptic time. This analysis is based on a semi-objective weighting of fix information based on the historical accuracy of the fix platform and the meteorological features used for the fix. The interpolated warning position reduces the weighting of any single fix and results in a more consistent movement and a warning position that is more representative of the larger-scale circulation. If the fix data are not available due to reconnaissance platform malfunction or communication problems, synoptic data or extrapolation from previous fixes are used.

b. TRACK FORECASTING

A preliminary forecast track is developed based on an evaluation of the rationale behind the previous warning and the guidance given by the most recent set of objective techniques and numerical prognoses. This preliminary track is then subjectively modified based on the following considerations:

(1) The prospects for recurvature or erratic movement are evaluated. This determination is based primarily on the present and forecast positions and amplitudes of the middle-tropospheric, mid-latitude troughs and ridges as depicted on the latest upper-air analysis and numerical forecasts.

(2) Determination of the best steering level is partly influenced by the maturity and vertical extent of the tropical cyclone. For mature tropical cyclones located south of the subtropical ridge axis, forecast changes in speed of movement are closely correlated with anticipated changes in the intensity or relative position of the ridge. When steering currents are relatively weak, the tendency for tropical

cyclones to move northward due to internal forces is an important consideration.

(3) Over the 12- to 72-hour (12- to 48-hour in the southern hemisphere) forecast period, speed of movement during the early forecast period is usually biased towards persistence, while the later forecast periods are biased towards objective techniques. When a tropical cyclone moves poleward, and toward the mid-latitude steering currents, speed of movement becomes increasingly more biased toward a selective group of objective techniques capable of estimating acceleration.

(4) The proximity of the tropical cyclone to other tropical cyclones is closely evaluated to determine if there is a possibility of interaction.

A final check is made against climatology to determine whether the forecast track is reasonable. If the forecast deviates greatly from one of the climatological tracks, the forecast rationale will be reappraised.

c. INTENSITY FORECASTING

Heavy reliance is placed on the empirically derived Dvorak (1984) model for forecasting tropical cyclone intensity. Other techniques used for forecasting intensity are extrapolation of synoptic wind and pressure data and climatology. An evaluation of the entire synoptic situation is made, including the location of major troughs and ridges, the position and intensity of any nearby Tropical Upper-Tropospheric Troughs (TUTTs), the vertical and horizontal extent of the tropical cyclone's circulation and the extent of the associated upper-level outflow pattern. Each intensity forecast is affected by the accompanying forecast track and environmental influences along that track; such as, terrain, vertical wind shear and extratropical weather features.

d. WIND-RADII FORECASTING

A new wind profile and steering diagnostic is being used at JTWC. The technique is the result of efforts by Dr. G. J. Holland (Office of Naval Research contractor) and Maj. J. Martin. The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. For the first time, diagnoses also include asymmetric areas of winds caused by tropical cyclone movement. Size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "Beta-drift". The Holland/Martin wind radii technique replaces the more general Huntley (1980) technique.

8. WARNINGS

Tropical cyclone warnings are issued when a closed circulation is evident and maximum sustained winds are forecast to increase to 34 kt (18 m/sec) within 48-hours, or if the tropical cyclone is in such a position that life or property may be endangered within 72-hours. Warnings may also be issued in other situations if it is determined that there is a need to alert military or civil interests to threatening tropical weather conditions.

Each tropical cyclone warning is numbered sequentially and includes the following information: the position of the surface center; estimate of the position accuracy and the supporting reconnaissance (fix) platforms; the direction and speed of movement during the past six hours (past 12-hours in the southern hemisphere); the intensity and radial extent of over 30-, 50-, and 100-knot surface winds, when applicable. At forecast intervals of 12-, 24-, 48-, and 72-hours (12-, 24-, and 48-hours in the southern hemisphere), information on the tropical cyclone's anticipated position, intensity and wind radii are also provided. Vectors indicating the mean direction and mean speed between forecast positions are also included in all warnings.

Warnings in the western North Pacific and North Indian Oceans are issued every six hours valid at standard times: 0000Z, 0600Z, 1200Z and 1800Z (every 12-hours: 0000Z, 1200Z or 0600Z, 1800Z in the southern hemisphere). All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one-half hours, so that recipients will have a reasonable expectation of having all warnings "in hand" by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z).

Warning forecast positions are later verified against the corresponding "best track" positions (obtained during detailed post-storm analyses to determine the most probable path and intensity of the cyclone). A summary of the verification results for 1988 is presented in Chapter V.

9. PROGNOSTIC REASONING MESSAGES

This plain language message is intended to provide meteorologists with the reasoning behind the latest forecast. For tropical depressions, tropical storms, typhoons and super typhoons in the western North Pacific Ocean, prognostic reasoning messages are transmitted following each warning. This is a change from 1987, when prognostic reasoning messages for western North Pacific tropical storms, typhoons and super typhoons were transmitted after the 0000Z and 1200Z warnings, or whenever the previous forecast reasoning was no longer valid.

In addition to this message, prognostic reasoning information, applicable to all customers, is provided in the remarks section of warnings when significant forecast changes are made or when deemed appropriate by the TDO.

10. TROPICAL CYCLONE FORMATION ALERTS

Tropical Cyclone Formation Alerts (TCFAs) are issued whenever interpretation of satellite imagery and other meteorological data indicate that the formation of a significant tropical cyclone is likely. These Alerts will specify a valid period not to exceed twenty-four hours and must either be cancelled, reissued, or superseded by a tropical cyclone warning prior to the expiration of the valid time.

11. SIGNIFICANT TROPICAL WEATHER ADVISORIES

This product contains a general, non-technical description of all tropical disturbances in JTWC's area of responsibility (AOR) and an assessment of their potential for further (tropical cyclone) development. In addition, all tropical cyclones in warning status are briefly discussed. Two separate messages are issued daily and are valid for a 24-hour period. The Significant Tropical Weather Advisory for the western Pacific Ocean (ABPW PGTW) covers the area east of 100° East longitude to the dateline and is issued by 0600Z. The Significant Tropical Weather Advisory for the Indian Ocean (ABIO PGTW) covers the area west of 100° East longitude to the coast of Africa and is issued by 1800Z. These are reissued whenever the situation warrants. For each suspect area, the words "poor", "fair", or "good" are used to describe the potential for development. "Poor" will be used to describe a tropical disturbance in which meteorological conditions are currently unfavorable for development; "fair" will be used to describe a tropical disturbance in which the meteorological conditions are favorable for development but significant development has not commenced; and "good" will be used to describe the potential for development of a tropical disturbance covered by a Tropical Cyclone Formation Alert.

CHAPTER II - RECONNAISSANCE AND FIXES

1. GENERAL

The Joint Typhoon Warning Center depends on reconnaissance to provide necessary, accurate, and timely meteorological information in support of advisories, alerts and warnings. JTWC relies primarily on three reconnaissance platforms: aircraft, satellite, and radar. In data rich areas, synoptic data are also used to supplement the above. Optimum use of all available reconnaissance resources is obtained through the Selective Reconnaissance Program (SRP); various factors are considered in selecting a specific reconnaissance platform including capabilities and limitations, and the tropical cyclone's threat to life and property both afloat and ashore. A summary of reconnaissance fixes received during 1988 is included in Section 6 of this chapter.

2. RECONNAISSANCE AVAILABILITY

a. AIRCRAFT

Due to budgetary constraints, 1987 was the final year for dedicated aircraft weather reconnaissance in the western North Pacific. The thrust in 1988 was to increase the frequency and reliability of commercial/military airways meteorological reports, thus enhancing synoptic analysis, particularly in data sparse regions.

Limited aircraft of opportunity were available in the western North Pacific, in 1988, for use as synoptic track missions. Aircraft of opportunity can provide direct measurements of standard pressure-level heights, temperature and flight-level wind data. These data, plus the use of airborne radar, can provide the forecaster vital information on changing tropical cyclone characteristics.

b. SATELLITE

Satellite fixes from Air Force/Navy ground sites and Navy ships provide day and night coverage in JTWC's area of responsibility. Interpretation of this satellite imagery provides tropical cyclone positions and estimates of current and forecast intensities through the Dvorak technique.

c. RADAR

Land-based radar remotely senses and maps precipitation within tropical cyclones in the proximity (usually within 175 nm (324 km)) of radar sites in the Republic of the Philippines, Taiwan, Hong Kong, Japan, South Korea, Kwajalein and Guam. In 1987 the USAF upgraded the radars at Yongsan AB, South Korea; Yokota AB, Japan; Kadena AB, Okinawa, Japan; and Andersen AFB, Guam. (The upgrade included increased range, continuous clockwise or counterclockwise scan, a range height indicator to an altitude of 21 km (13 nm) in 1 km (0.6 nm) intervals, a digital video integrator/processor, range normalization, a color enhanced digital remote scope and local area/operations area mapping program.) These new radars are a welcome improvement to the existing network. The next upgrade will be the arrival of the first next generation Doppler radars in the early 1990's.

d. SYNOPTIC

JTWC also determines tropical cyclone positions based on the analysis of the surface/gradient-level synoptic data. These positions were helpful in situations where the vertical structure of the tropical cyclone was weak or accurate surface positions from aircraft or satellite were not available.

3. AIRCRAFT RECONNAISSANCE SUMMARY

There were no vortex fix or investigative missions flown into western North Pacific tropical cyclones in 1988. A synoptic track and airborne radar fix were provided on Typhoon Roy (01W) in January by aircraft of opportunity. These data described the mid-level steering flow and center location.

4. SATELLITE RECONNAISSANCE SUMMARY

The USAF provides satellite reconnaissance support to JTWC through the DMSP Tropical Cyclone Reporting Network (DMSP Network), which consists of tactical sites and a centralized facility. Tactical DMSP sites monitoring DMSP, NOAA and geostationary satellite data are located at Nimitz Hill, Guam; Clark AB, Republic of the Philippines; Kadena AB, Okinawa, Japan; Osan AB, Republic of Korea; and Hickam AFB, Hawaii. These sites provide a combined coverage that includes most of JTWC's area of responsibility in the western North Pacific, from near the dateline westward to the Malay Peninsula. For the remainder of its AOR, JTWC relies on the AFGWC to provide coverage using stored satellite data. The Naval Oceanography Command Detachment, Diego Garcia, furnishes interpretation of NOAA polar orbiting coverage in the central Indian Ocean and USN ships equipped for direct satellite readout contribute supplementary support.

AFGWC, located at Offutt AFB, Nebraska, is the centralized member of the DMSP network. In support of JTWC, AFGWC processes stored imagery from DMSP and NOAA spacecraft. Stored imagery is recorded onboard the spacecraft as they pass over the earth and later down-linked to AFGWC via a network of command readout sites and communication satellites. This enables AFGWC to obtain the coverage necessary to fix all tropical cyclones within JTWC's AOR. AFGWC has the primary responsibility to provide tropical cyclone reconnaissance over the entire Indian Ocean, southwest Pacific, and the area near the dateline in the western North Pacific Ocean. Additionally, AFGWC can be tasked to provide tropical cyclone support in the entire western North Pacific as backup to coverage routinely available in that region.

The hub of the DMSP network is Detachment 1, First Weather Wing (Det 1, 1WW), colocated with JTWC at Nimitz Hill, Guam. Based on available satellite coverage, Det 1, 1WW is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates and forecast intensities. When a particular satellite pass is selected to support the development of JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same pass. This "dual-site" concept provides the necessary redundancy to virtually guarantee JTWC a satellite fix on the tropical cyclone.

The network provides JTWC with several products and services. The main service is one of monitoring the AOR for indications of tropical cyclone development. If an area exhibits potential for development, JTWC is notified. Once JTWC issues either a Tropical Cyclone Formation Alert or warning, the network is tasked to provide three products: tropical cyclone positions, current intensity estimates and forecast intensities. Each satellite tropical cyclone position is assigned a Position Code Number (PCN) to indicate the accuracy of the fix position. The PCN is determined by the availability of visible landmarks in the image that can be used as references for precise gridding and the degree of organization of the tropical cyclone's cloud system (Table 2-1).

TABLE 2-1

POSITION CODE NUMBERS (PCN)

PCN	METHOD FOR CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

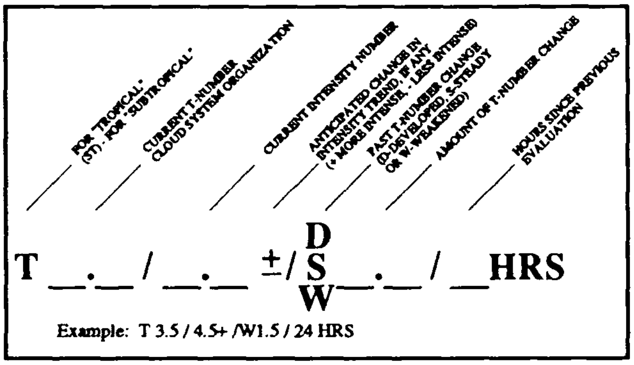


Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the previous evaluation conducted 24-hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

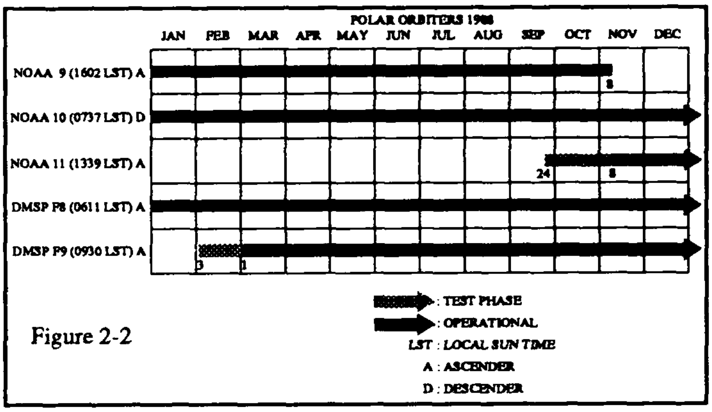


Figure 2-2

Starting in 1987, Detachment 1, First Weather Wing increased the number of estimates of the tropical cyclone's current intensity from two to four per day once a tropical cyclone formation alert or tropical cyclone warning was issued. Current intensity estimates and 24-hour intensity forecasts are made using the Dvorak technique (NOAA Technical Report NESDIS 11) for both visual and enhanced infrared imagery (Figure 2-1).

Figure 2-2 shows the status of operational polar orbiting spacecraft. Two DMSP spacecraft were operational in 1988. The year began with one operational DMSP satellite, the 19543 (F8) spacecraft. After overheating forced a temporary shutdown on 3 December 1987, the Special (passive) Sensor, Microwave Imager (SSM/I) on the F8 spacecraft was reactivated in mid-January 1988. The 20542 (F9) DMSP satellite was launched 3 February as a replacement for the 18541 (F7) satellite, which failed 17 October 1987. The thermal channel used for intensity estimates began to degrade shortly after launch and was of marginal use at year's end. The NOAA 10 spacecraft performed well throughout the year. The NOAA 11 was launched 24 September and replaced the aging NOAA 9 satellite on 8 November.

During 1988, data from the DMSP network was the primary input to warnings and best tracks in the western North Pacific. This increased emphasis on satellite data resulted in almost all the warnings being based on satellite reconnaissance.

The DMSP network provided JTWC with a total of 2,044 satellite fixes on 27 tropical cyclones in the western North Pacific Ocean. In addition, 117 fixes were made on tropical cyclones in the North Indian Ocean and 1144 in the southern hemisphere. A comparison of those fixes and their corresponding best tracks is shown in Tables 2-2A and 2-2B. (Note: Those fixes which were out of limits when compared with the best track are not included.) The network also provided an additional 224 fixes on tropical disturbances which did not develop into significant tropical cyclones. The standard relationship between tropical cyclone "T-number", maximum surface wind speed (Dvorak, 1984) and minimum sea-level pressure (Atkinson and Holliday, 1977) is outlined in Table 2-3.

TABLE 2-2A

MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)

	WESTERN NORTH PACIFIC OCEAN		NORTH INDIAN OCEAN	
PCN	1978-1987 AVERAGE	1988 AVERAGE	1980-1987 AVERAGE	1988 AVERAGE
1	14.2 (1737)	13.4 (78)	16.9 (42)	7.2 (2)
2	15.6 (2582)	13.7 (337)	16.9 (9)	11.3 (4)
3	21.2 (2488)	18.5 (82)	24.8 (34)	24.5 (8)
4	22.2 (2047)	16.7 (281)	45.1 (21)	25.2 (5)
5	37.5 (4294)	30.2 (185)	38.3 (313)	37.4 (30)
6	38.4 (5023)	30.9 (973)	40.5 (417)	38.7 (64)
1&2	15.0 (4319)	13.6 (415)	17.0 (51)	9.9 (6)
3&4	21.7 (4535)	17.1 (363)	32.5 (55)	24.8 (13)
5&6	38.0 (9317)	30.8 (1158)	39.6 (730)	38.3 (94)
TOTAL	28.4 (18171)	24.5 (1936)	37.8 (836)	35.2 (113)

TABLE 2-2B

MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)

PCN	1985 - 1987 AVERAGE	1988 AVERAGE
1	16.6 (82)	15.2 (21)
2	16.1 (442)	17.9 (122)
3	35.9 (112)	25.4 (13)
4	27.0 (408)	27.1 (130)
5	40.8 (474)	39.2 (74)
6	36.4 (2938)	40.1 (713)
1 & 2	16.2 (524)	17.5 (143)
3 & 4	28.9 (520)	26.9 (143)
5 & 6	37.0 (3412)	40.0 (787)
TOTALS	33.6 (4456)	35.3 (1073)

TABLE 2-3

MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

TROPICAL CYCLONE INTENSITY NUMBER	WIND SPEED	MSLP (NW PACIFIC)
0.0	<25	- - - -
0.5	25	- - - -
1.0	25	- - - -
1.5	25	- - - -
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	954
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

5. RADAR RECONNAISSANCE SUMMARY

Twelve of the twenty-seven significant tropical cyclones in the western North Pacific during 1988 passed within range of land-based radar with sufficient cloud pattern organization to be fixed. The land-based radar fixes that were obtained and transmitted to JTWC totaled 430. (Only one radar fix was obtained by aircraft of opportunity.)

The WMO radar code defines three categories of accuracy: good (within 10 km (5 nm)), fair (within 10-30 km (5-16 nm)), and poor (within 30-50 km (16-27 nm)). Of the 428 radar fixes encoded in this manner; 169 were good, 120 were fair, and 139 were poor. Compared to JTWC's best track, the mean vector deviation for land-based radar sites was 19 nm (35 km). Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement through even the most difficult erratic tracks.

The availability of data from radar sites in the Republic of Philippines was of concern. In 1988 these radar sites provided a valuable but limited number of reports on tropical cyclones. Reports were received from only two stations, in contrast to five in 1987. As in previous years, no radar reports were received on North Indian Ocean or southern hemisphere tropical cyclones.

6. TROPICAL CYCLONE FIX DATA

A total of 2,474 fixes on twenty-seven western North Pacific tropical cyclones and 117 fixes on five North Indian Ocean tropical cyclones were received at JTWC. Table 2-4A and Table 2-4B delineate the number of fixes per platform for each individual tropical cyclone for the western North Pacific and North Indian Oceans respectively. Season totals and percentages are also indicated. (Table 2-4C provides the same information for the South Pacific and South Indian Oceans.)

TABLE 2-4A

WESTERN NORTH PACIFIC
FIX PLATFORM SUMMARY FOR 1988

WESTERN NORTH PACIFIC		SATELLITE	RADAR	TOTAL*
TY ROY	(01W)	155	60	215
TY SUSAN	(02W)	75	35	110
TD 03W	(03W)	29	0	29
TY THAD	(04W)	96	26	122
TS VANESSA	(05W)	76	8	84
TY WARREN	(06W)	141	30	171
TS AGNES	(07W)	33	0	33
TS BILL	(08W)	43	0	43
TS CLARA	(09W)	36	0	36
TY DOYLE	(10W)	96	0	96
TS ELSIE	(11W)	39	0	39
TY FABIAN	(12W)	81	0	81
TS GAY	(13W)	21	0	21
TY HAL	(14W)	110	18	128
TY ULEKI	(01C)	62	0	62
TS IRMA	(15W)	51	0	51
TS JEFF	(16W)	36	0	36
TS KIT	(17W)	51	9	60
TS LEE	(18W)	64	8	72
TS MAMIE	(19W)	48	0	48
STY NELSON	(20W)	125	184	309
TY ODESSA	(21W)	104	0	104
TY PAT	(22W)	81	9	90
TY RUBY	(23W)	140	42	182
TY SKIP	(24W)	133	0	133
TY TESS	(25W)	55	0	55
TS VAL	(26W)	63	1	64
TOTALS		2044	430	2474
PERCENTAGE OF TOTALS		83%	17%	100%

* NO AIRCRAFT OR SYNOPTIC FIXES WERE RECEIVED

TABLE 2-4B

NORTH INDIAN OCEAN
FIX PLATFORM SUMMARY FOR 1988

TROPICAL CYCLONE	SATELLITE*
TC 01A	20
TC 02B	15
TC 03B	11
TC 04B	55
TC 05B	16
TOTAL NUMBER OF FIXES	117

* NO SYNOPTIC FIXES WERE RECEIVED

TABLE 2-4C

SOUTH PACIFIC AND SOUTH INDIAN OCEANS
FIX PLATFORM SUMMARY FOR 1988

TROPICAL CYCLONES		SATELLITE	SYNOPTIC	TOTAL**
TC 01S	- - - -	65	0	65
TC 02S	- - - -	14	0	14
TC 03S	ARINY	79	0	79
TC 04P	- - - -	37	0	37
TC 05S	BERNANDRO	43	0	43
TC 06P	AGI	97	0	97
TC 07P	ANNE	93	2	95
TC 08S	CALIDERA	18	0	18
TC 09S	DOAZA	59	0	59
TC 10S	FREDERIC	47	0	47
TC 11S	GWENDA *	95	0	95
TC 12P	CHARLIE	111	0	111
TC 13P	BOLA	123	0	123
TC 14S	- - - -	21	0	21
TC 15P	CILLA	14	0	14
TC 16S	GASITAO	64	0	64
TC 17S	- - - -	2	0	2
TC 18S	HELY	11	0	11
TC 19P	DOVI	82	0	82
TC 20S	IARISENA	24	0	24
TC 21S	- - - -	25	0	25
TOTAL NUMBER OF FIXES		1144	2	1146

* ALSO NAMED EZENINA

** NO RADAR FIXES WERE RECEIVED

Intentionally left blank.

CHAPTER III - SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

1. GENERAL

During the calendar year 1988, JTWC issued warnings on 27 tropical cyclones in the western North Pacific - one super typhoon, 12 typhoons, 13 tropical storms and one tropical depression. This includes Typhoon Uleki (01C), which initially developed in the central North Pacific (Table 3-1). The total number of western North Pacific tropical cyclones is lower than the climatological mean of 30.7, and two above the 1987 total (Table 3-2). Five tropical cyclones - one of typhoon and four of tropical storm intensity - developed in the North Indian Ocean. This is average. The climatological mean is 4.7. During 1988, warnings were issued on a total of 32 northern hemisphere tropical cyclones. A chronology of western North Pacific and North Indian Ocean tropical cyclones is provided in Figure 3-1.

For the year, there were 114 "warning days" in the western North Pacific. A warning day is defined as a day during which JTWC issued warnings on at least one tropical cyclone. A "one-cyclone day" refers to a day when we were warning on only one tropical cyclone. A "two-cyclone day" refers to a day when we warned on two different tropical cyclones simultaneously. A "three-cyclone day" means JTWC was warning on three tropical cyclones at once. Considering only the western North Pacific, there were 15 two-cyclone days and four three-cyclone days (Table 3-3). When North Indian Ocean tropical cyclones are included, there were 128 warning days of which 16 were two-cyclone days and four were three-cyclone days. There were no four-cyclone or five-cyclone days. Thus, JTWC was in northern hemisphere warning status 35 percent of the year; we were in a multiple-cyclone situation (that is, warning on two or more tropical cyclones at the same time) for 20 days or six percent of the year.

JTWC issued 471 warnings on 27 western North Pacific tropical cyclones and 44 warnings on five North Indian Ocean tropical cyclones, for a grand total of 515 warnings. There were 33 initial Tropical Cyclone Formation Alerts issued for western North Pacific disturbances and four for the North Indian Ocean. Twenty-six western North Pacific and four North Indian Ocean tropical cyclones developed subsequent to the issuance of an Alert. Only one western North Pacific tropical cyclone-Tropical Storm Elsie (11W)-regenerated, and an Alert was issued prior to regeneration. Typhoon Uleki (01C) was passed to JTWC from CPHC while in warning status, so JTWC did not issue an Alert (Table 3-4). In the western North Pacific, the false alarm rate was 21 percent and the mean lead time (to issuance of the first warning) was 8.5-hours. For the North Indian Ocean, the false alarm rate was zero and the mean lead time was 5.1 hours. An Alert was not issued for Tropical Cyclone 02B.

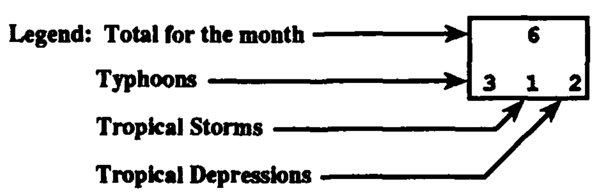
TABLE 3-1

WESTERN NORTH PACIFIC
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS KT (M/SEC)	ESTIMATED MSLP - MB
(01W)	TY ROY	08 JAN - 18 JAN	41	115 (59)	927
(02W)	TY SUSAN	30 MAY - 03 JUN	17	80 (41)	963
(03W)	TD 03W	04 JUN - 05 JUN	6	30 (15)	1000
(04W)	TY THAD	20 JUN - 25 JUN	21	70 (36)	972
(05W)	TS VANESSA	26 JUN - 29 JUN	12	45 (23)	991
(06W)	TY WARREN	12 JUL - 20 JUL	30	115 (59)	927
(07W)	TS AGNES	29 JUL - 30 JUL	8	40 (21)	994
(08W)	TS BILL	07 AUG - 08 AUG	5	45 (23)	991
(09W)	TS CLARA	10 AUG - 12 AUG	6	45 (23)	991
(10W)	TY DOYLE	15 AUG - 21 AUG	24	115 (59)	927
(11W)	TS ELSIE	28 AUG - 29 AUG	6	35 (18)	997
(11W)	TS ELSIE*	31 AUG	4	45 (23)	991
(12W)	TY FABIAN	30 AUG - 03 SEP	18	75 (39)	968
(13W)	TS GAY	02 SEP - 04 SEP	6	45 (23)	991
(14W)	TY HAL	08 SEP - 17 SEP	37	105 (54)	938
(01C)	TY ULEKI	08 SEP - 13 SEP	21	90 (46)	954
(15W)	TS IRMA	12 SEP - 15 SEP	16	55 (28)	984
(16W)	TS JEFF	14 SEP - 16 SEP	9	45 (23)	991
(17W)	TS KIT	19 SEP - 22 SEP	12	55 (28)	984
(18W)	TS LEE	21 SEP - 24 SEP	15	55 (28)	984
(19W)	TS MAMIE	22 SEP - 23 SEP	4	45 (23)	991
(20W)	STY NELSON	01 OCT - 08 OCT	30	140 (72)	898
(21W)	TY ODESSA	11 OCT - 16 OCT	22	90 (46)	954
(22W)	TY PAT	18 OCT - 22 OCT	17	75 (39)	968
(23W)	TY RUBY	21 OCT - 28 OCT	30	125 (64)	916
(24W)	TY SKIP	03 NOV - 11 NOV	30	125 (64)	916
(25W)	TY TESS	04 NOV - 06 NOV	10	65 (33)	976
(26W)	TS VAL	22 DEC - 26 DEC	14	55 (28)	984
		TOTAL	471		

* REGENERATED

TABLE 3-2 LEGEND



The criteria used in Table 3-2 are as follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

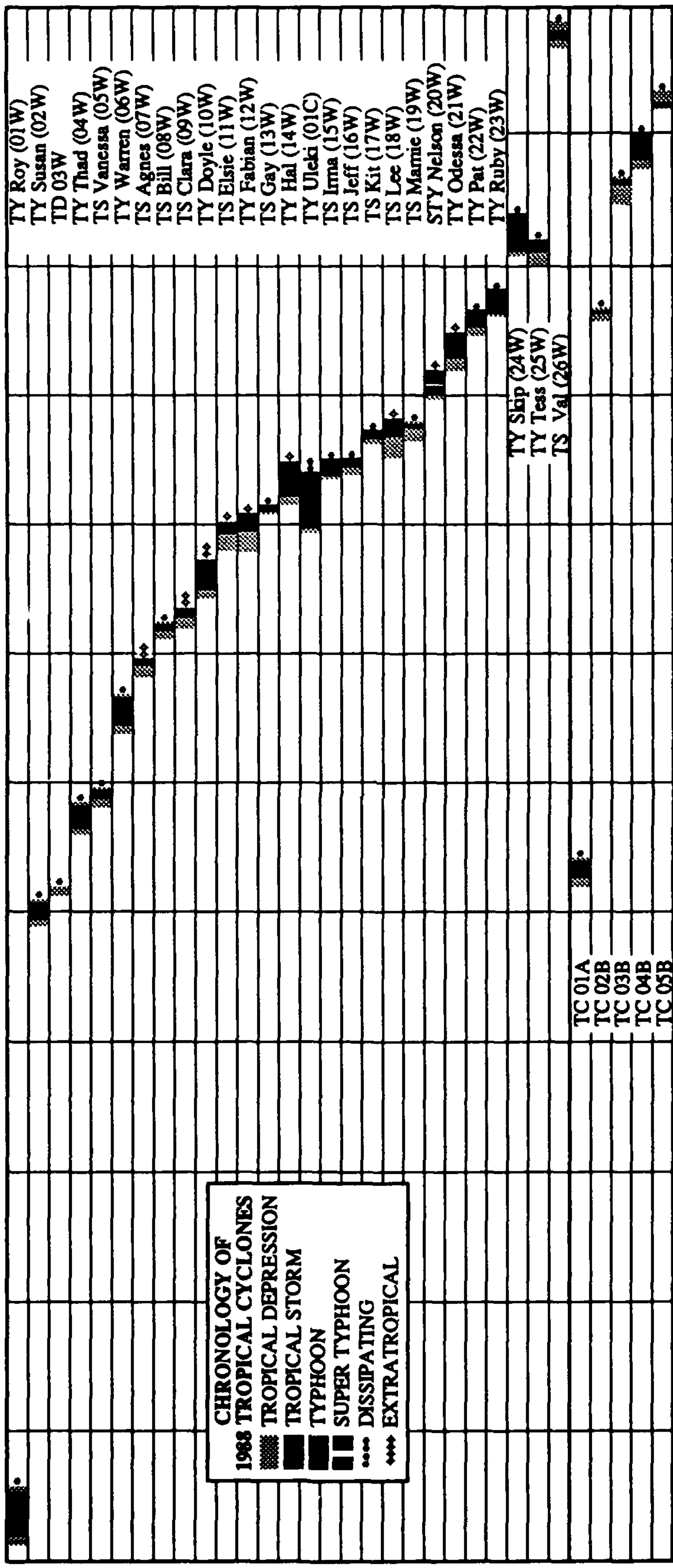
3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-2

WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
(1959-1988) AVG	0.6	0.3	0.6	0.7	1.2	2.1	4.5	6.2	5.7	4.5	2.8	1.4	30.6
CASES	17	9	18	22	37	63	134	185	172	136	83	43	919

Figure 3-1



CHRONOLOGY OF
1988 TROPICAL CYCLONES
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON
DISSIPATING
EXTRATROPICAL
TY Roy (01W)
TY Susan (02W)
TD 03W
TY Thad (04W)
TS Vanessa (05W)
TY Warren (06W)
TS Agnes (07W)
TS Bill (08W)
TS Clara (09W)
TY Doyle (10W)
TS Elsie (11W)
TY Fabian (12W)
TS Gay (13W)
TY Hal (14W)
TY Uleki (01C)
TS Irma (15W)
TS Jeff (16W)
TS Kit (17W)
TS Lee (18W)
TS Mamie (19W)
STY Nelson (20W)
TY Odessa (21W)
TY Pat (22W)
TY Ruby (23W)
TY Skip (24W)
TY Tess (25W)
TS Val (26W)
TC 01A
TC 02B
TC 03B
TC 04B
TC 05B
January
February
March
April
May
June
July
August
September
October
November
December

TABLE 3-3

WESTERN NORTH PACIFIC TROPICAL CYCLONE SUMMARY

TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.3	0.4	0.7	1.1	2.0	2.9	3.2	2.4	2.0	0.9	16.3
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228

(1959 - 1988)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.3	0.1	0.2	0.5	0.7	1.0	2.7	3.2	3.3	3.0	1.7	0.7	17.4
CASES	8	2	6	15	20	31	81	96	98	91	50	20	518

TROPICAL STORMS AND TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.4	0.5	0.8	1.6	3.0	3.9	4.1	3.3	2.8	1.1	22.0
CASES	6	1	6	7	11	22	42	54	58	46	39	16	308

(1959 - 1988)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.5	0.3	0.5	0.7	1.0	1.8	4.1	5.3	5.0	4.1	2.6	1.3	27.2
CASES	16	9	14	21	31	53	122	160	150	122	78	38	814

FORMATION ALERTS: 26 OF 33 INITIAL FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES (NOT INCLUDING ONE ON A SYSTEM THAT REGENERATED). TROPICAL CYCLONE FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1988.

WARNINGS:

NUMBER OF CALENDAR WARNING DAYS: 114

NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 15

NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 4

TABLE 3-4

TROPICAL CYCLONE FORMATION ALERT SUMMARY
WESTERN NORTH PACIFIC OCEAN

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	FALSE ALARM RATE
1975	34	25	25	26%
1976	34	25	25	26%
1977	26	20	21	23%
1978	32	27	32	16%
1979	27	23	28	15%
1980	37	28	28	24%
1981	29	28	29	3%
1982	36	26	28	28%
1983	31	25	25	19%
1984	37	30	30	19%
1985	39	26	27	33%
1986	38	27	27	29%
1987	31	24	25	23%
1988	33	26	27	21%
(1975-1988) AVERAGE	33.3	25.7	26.9	21.8%
TOTALS	464	360	377	

2. WESTERN NORTH PACIFIC TROPICAL CYCLONES

Distinguishing features of the 1988 western North Pacific tropical cyclone season were the low number of super typhoons (1), the short average lifespan of the tropical cyclones, the aclimatic location of the monsoon trough and an active Tropical Upper-Tropospheric Trough (TUTT). The northward displacement of the monsoon trough during the summer and early fall and the active TUTT may have accounted for the relatively large number of tropical cyclones that had anomalous tracks. The normal lifespan of a tropical cyclone in the western North Pacific usually exceeds four warning days. This year JTWC encountered a large number of tropical cyclones (13) that were in warning status for four days or less. The short lifespans led to a relatively low number of warnings and forecast verifications.

JANUARY THROUGH MAY

Typhoon Roy (01W) was only the second typhoon in the past twelve years to develop in the western North Pacific during January. The typhoon's near miss of Guam resulted in the most destruction since Super Typhoon Pamela (1976) struck the island. After Roy (01W) there was a long break in activity until the end of May. The synoptic pattern during the last week of May was anomalous, with low-level southwesterlies extending across the northern Philippine Sea into the northern Marianas and southern Bonin Islands. Surface pressures in the monsoon trough were 4 to 5 mb below normal. Cyclonic vortices in the trough were transitory until Typhoon Susan (02W) formed off the coast of Luzon.

JUNE

As Susan (02W) moved northeastward, Tropical Depression 03W developed in the enhanced low-level southwesterly monsoonal flow left behind Susan (02W). Then Tropical Depression 03W moved into a subsidence area over China and dissipated. A two week hiatus in tropical cyclone activity followed. Then Typhoon Thad (04W) formed in the eastern Carolines. It tracked over 2000 nm (3704 km) during its lifetime, recurving just east of the island of Luzon and passing 80 nm (148 km) southeast of Okinawa. With Thad (04W) weakening over water to the north, Tropical Storm Vanessa (05W) generated to the south in the Philippine Sea. It was the first "straight-runner" of the year. Vanessa (05W) tracked across the Philippine Islands and into the South China Sea before dissipating over southern China.

JULY

Almost two weeks passed after Vanessa's (05W) demise before Typhoon Warren (06W) developed in the eastern Caroline Islands. Warren (06W) was the second tropical cyclone of the year to threaten Guam. Warren (06W) was the second "straight-runner" of the year and maintained a west-northwestward track during almost its entire lifetime. The system skirted northern Luzon prior to making landfall in southeastern China. Tropical Storm Agnes (07W) followed a week later and was noteworthy for several reasons. It was the last of only two tropical cyclones to develop in July, a month that normally averages five systems and played a major role in the changing synoptic pattern during late July. When Warren (06W) dissipated, the monsoon trough remained much farther north than normal. Agnes (07W) formed in the area of lower pressures southeast of Japan where the monsoon trough merged with a mid-latitude low pressure system to the northeast. Agnes (07W) followed the path of least resistance and accelerated north-northeastward along the trough axis.

AUGUST

Once Agnes (07W) went extratropical the monsoon trough underwent a major readjustment. It now stretched eastward from the Gulf of Tonkin, across the South China Sea, through the Luzon Strait and abruptly terminated near Okinawa. Tropical Storm Bill

(08W) consolidated rapidly at the eastern end of the monsoon trough, brushed by the island of Okinawa and reached a peak intensity of 45 kt (23 m/sec) before making landfall near Shanghai, China. Bill (08W) remained well organized even after making landfall, and caused widespread destruction and loss of life in China. The other four tropical cyclones that developed in August (Clara (09W), Doyle (10W), Elsie (11W) and Fabian (12W)) all formed north of 20° North latitude. Tropical Storm Clara (09W) began in the easterly trade winds as an area of weakly organized convection 540 nm (1,000 km) north of Wake Island. Clara (09W) initially tracked westward, then abruptly changed direction toward the north. Throughout its short lifespan, the system was consistently hindered by vertical wind shear and only peaked at an intensity of 45 kt (23 m/sec). Typhoon Doyle (10W) also fell into the track category of "other" due to its erratic behavior. Initially, Doyle (10W) moved rapidly toward the south-southwest and looped before tracking northeastward. To make the forecasts more complicated, Doyle (10W) interacted with a TUTT cell while maintaining typhoon intensity. Once Doyle (10W) was extratropical, Tropical Storm Elsie (11W) and Typhoon Fabian (12W) formed from persistent convection in the monsoon trough. Both displayed erratic movement during their early stages and underwent binary interaction before transitioning into extratropical systems.

SEPTEMBER

With Elsie (11W) and Fabian (12W) going extratropical, Tropical Storm Gay (13W) generated in the monsoon trough 420 nm (778 km) east of Okinawa and attained a peak intensity of 45 kt (23 m/sec). It took the path of least resistance and tracked up the trough to the northeast. Gay (13W) was short-lived. It was followed by a more normal synoptic situation, where the monsoon trough shifted equatorward. The monsoon trough later expanded, stretching from Vietnam to 175° East longitude, and spawned seven tropical cyclones. As Gay (13W) dissipated east of Japan and Uleki (01C) churned across the Central Pacific, Typhoon Hal (14W) formed just west of Wake Island. Its development was aided by upper-level divergence from a TUTT cell to its north. Hal (14W) combined with Typhoon Uleki (01C), Tropical Storm Irma (15W), and later with Tropical Storm Jeff (16W) to create two separate three-storm situations. In the meantime, Typhoon Uleki (01C) became the third hurricane in the past thirty years to form in the central North Pacific and cross the international dateline while in a warning status. Tropical Storms Irma (15W) and Jeff (16W) developed in Hal's (14W) strong low-level southwesterly inflow. As Hal (14W), with a large ragged eye, tracked northward, Irma (15W) and Jeff (16W) followed and were sheared away. Once Hal (14W) went extratropical east of Japan, Tropical Storm Kit (17W) developed in the monsoon trough 240 nm (444 km) east of the Philippine Islands. Kit (17W) was a "straight-runner" and tracked over the northern tip of Luzon. It made landfall over southern China, causing loss of life and property damage. While Kit (17W) was moving into Luzon, Tropical Storm Lee (18W) was slowly developing. Lee (18W) tracked over 1,300 nm (2408 km) during a four day period as an identifiable area of convection before the first warning was issued. It then moved northwestward before recurving to the northeast and tracking within 45 nm (83 km) southeast of Okinawa. Tropical Storm Mamie (19W) formed in tandem with Kit (17W) and was the second significant tropical cyclone to develop in the South China Sea. Mamie (19W) had an anomalous track. After a prolonged southwestward movement, it made a sharp turn and moved northward towards Hong Kong.

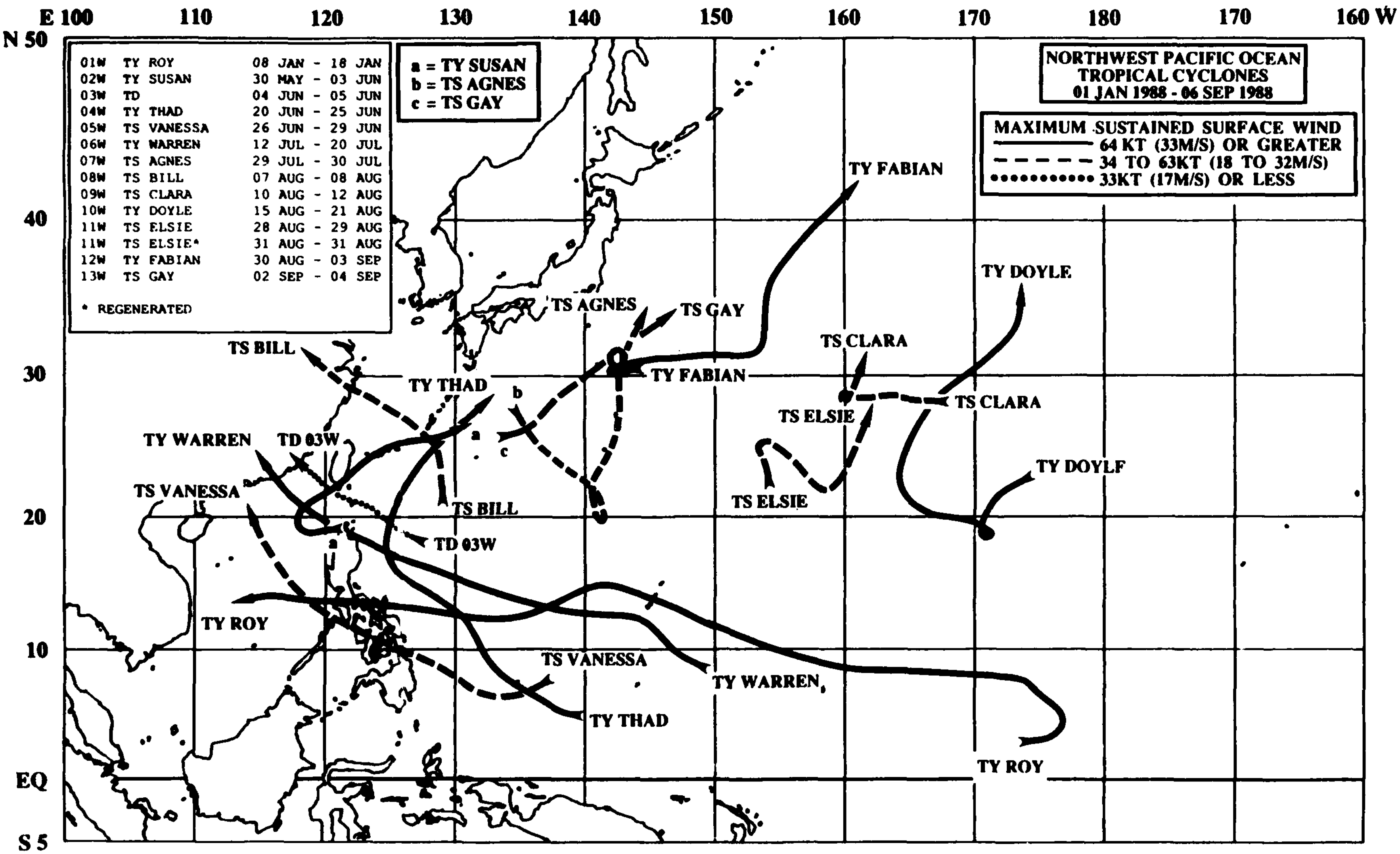
OCTOBER

Once Lee (18W) and Mamie (19W) were gone, there was a five day break before Super Typhoon Nelson (20W). It was the only super typhoon of 1988. The tropical cyclone initially moved westward towards the Philippine Islands, then west-northwestward as it tracked along the southwestern side of the subtropical ridge. A break in the ridge northwest of Nelson (20W) was identified and recurvature was correctly forecast. Nelson (20W) rapidly deepened for two days and reached super typhoon intensity shortly before recurvature. It then recurved and threatened Okinawa. Later, as the system became extratropical and accelerated toward the northeast, it also threatened Japan. While Nelson (20W) was weakening and accelerating, Typhoon Odessa (21W) began as an area of convection superimposed on broad low-level easterly tradewinds 600 nm (1111 km) south-southeast of Japan. During its first two days, Odessa (21W) moved rapidly to the west-northwest at a speed of 17 to 18 kt (32 to 33 km/hr). It began a gradual recurvature and moved toward the cooler, drier polar air mass from the Asian continent. Initially, interaction with cold air was expected to weaken the tropical cyclone. Instead, Odessa (21W) intensified into a midget typhoon, peaking at an intensity of 90 kt (46 m/sec). At the same time Tropical Storm Pat (22W) formed equatorward of 10° North latitude. The system tracked westward and attained a peak intensity of 75 kt (39 m/sec) prior to making landfall over central Luzon. Pat (22W) then moved west-northwestward across the South China Sea, tracking over the island of Hainan Dao and dissipating 30 nm (56 km) northeast of Hanoi, Vietnam. As Pat (22W) was winding down in the South China Sea, Typhoon Ruby (23W) was intensifying in the Philippine Sea. Ruby (23W) was the fifth tropical cyclone to track across the Philippine Islands and the third system to affect Vietnam in 1988. It tracked in a west-northwestward direction throughout its lifetime. The system reached a peak intensity of 125 kt (64 m/sec) shortly before making landfall in the Philippines. The result was extensive damage and loss of life. In the Philippines alone, at least 300 persons were killed and over 470,000 were left homeless. Ruby (23W) passed 65 nm (120 km) north-northeast of Manila, causing the strongest winds at Clark Air Base since 1978. Ruby (23W) then tracked into the South China Sea. Later, flash flooding from the dissipating system's torrential rainshowers resulted in over 100 deaths, hundreds of thousands homeless and widespread destruction of crops in Vietnam.

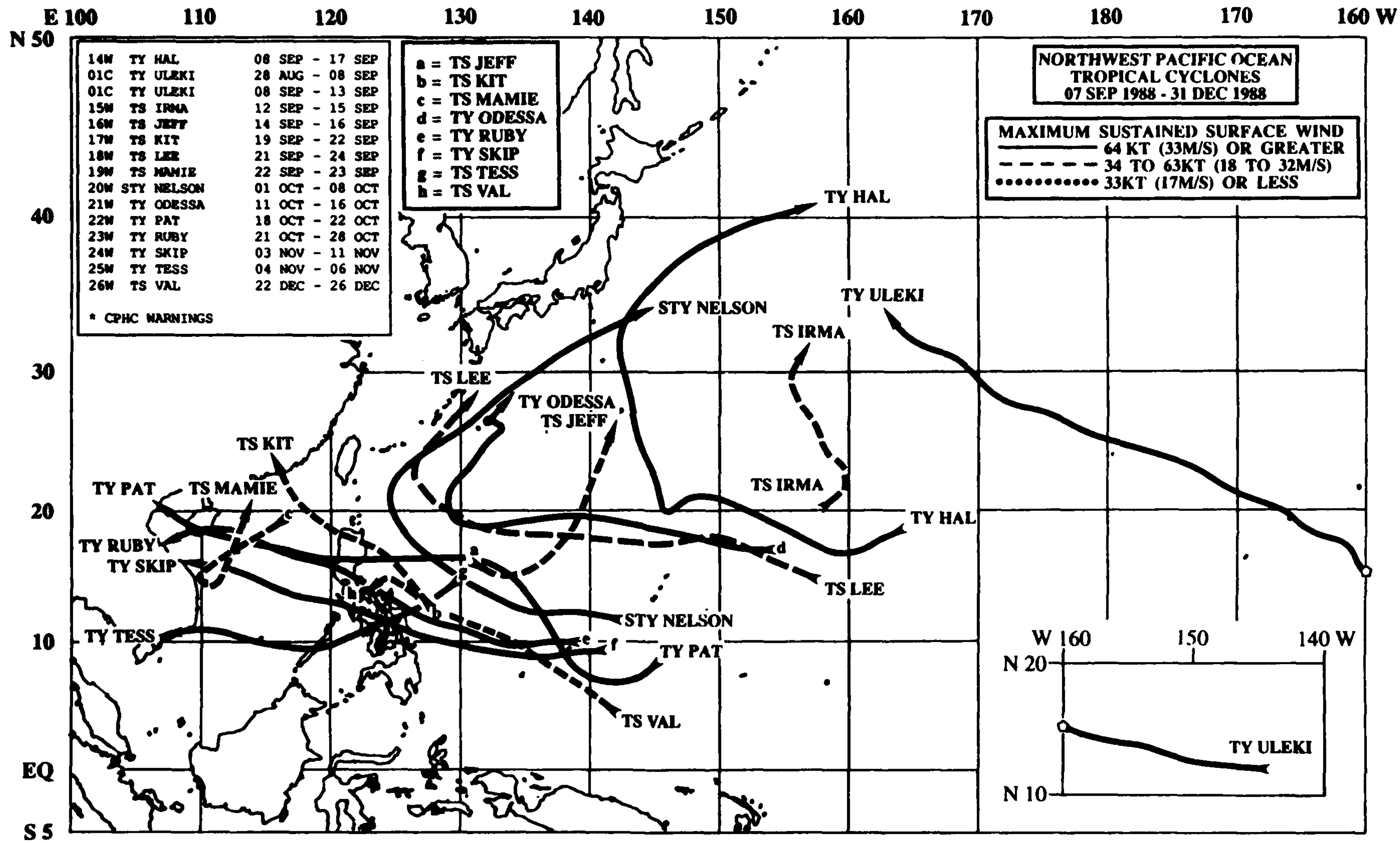
NOVEMBER THROUGH DECEMBER

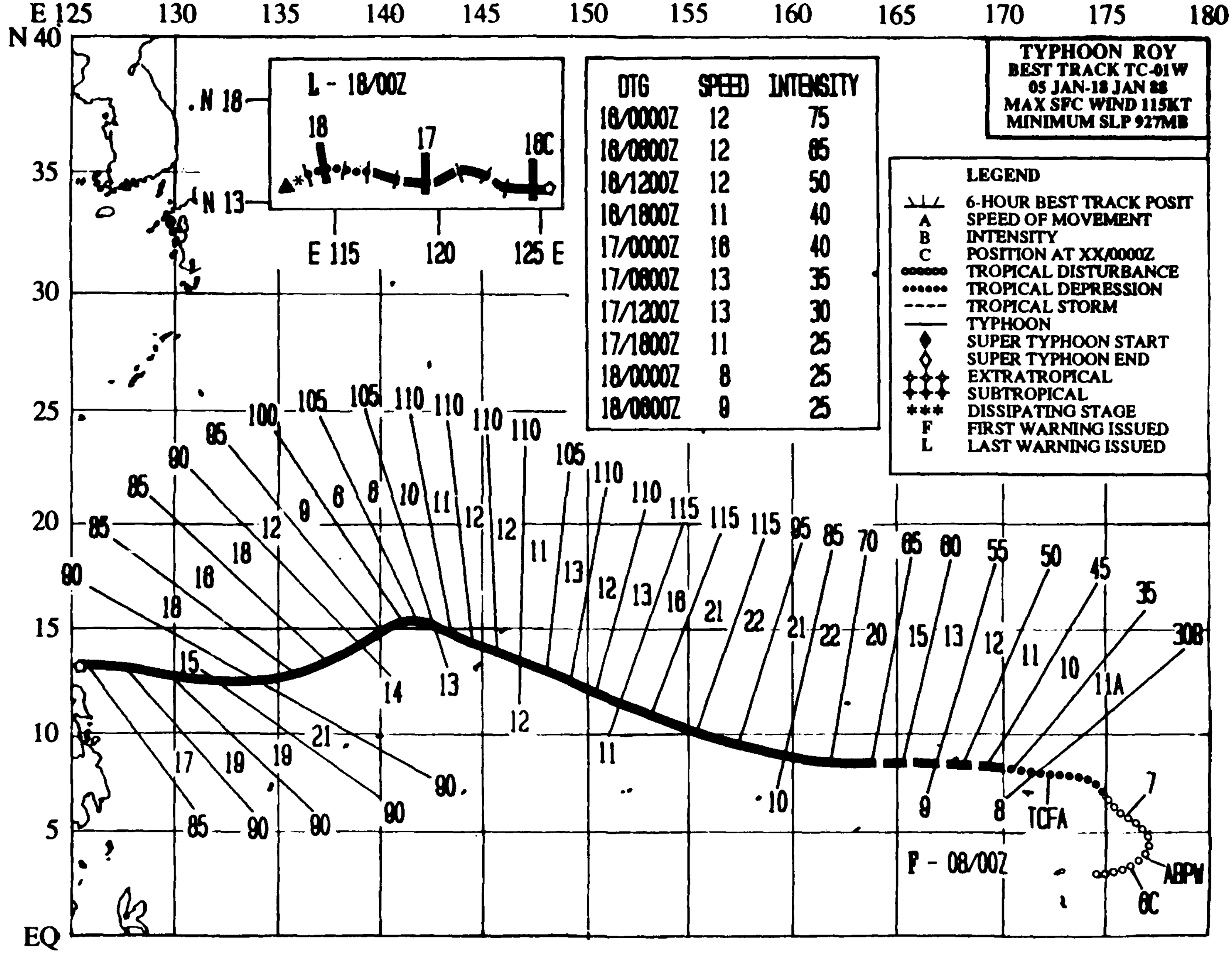
November marked a change in the synoptic flow pattern as the northeast monsoon became well established across the South China Sea and southeastern Asia. Easterly tradewinds dominated the Philippine Sea north of the near-equatorial trough. After a one week respite, Typhoon Skip (24W) appeared. It was a "straight-runner" and covered over 2,000 nm (3704 km) during its nine day lifetime. Skip (24W) tracked through the Philippine Islands and into the South China Sea. The system caused widespread damage to crops in the Philippines, killed over 100 persons and left over 600,000 homeless. Typhoon Tess (25W) formed in the near-equatorial trough before Skip (24W), but was slow to intensify. It was the only tropical cyclone to track across southern Vietnam this year. After Skip (24W) and Tess (25W), a break in tropical cyclone activity occurred until the third week of December. Following a massive outbreak of polar air from Asia, the southern Philippine Sea filled with convection and a near-equatorial trough formed. Tropical Storm Val (26W), which developed in the trough, proved difficult to position and hard to forecast. While decelerating from 25 kt (46 km/hr), Val (26W) peaked at an intensity of 55 kt (28 m/sec). Finally, the low-level circulation separated from the deep convection and was carried to the southwest along the edge of the winter monsoon.

Intentionally left blank.



NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
01 JAN 1988 - 06 SEP 1988
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
01W TY ROY 08 JAN - 18 JAN
02W TY SUSAN 30 MAY - 03 JUN
03W TD 04 JUN - 05 JUN
04W TY THAD 20 JUN - 25 JUN
05W TS VANESSA 26 JUN - 29 JUN
06W TY WARREN 12 JUL - 20 JUL
07W TS AGNES 29 JUL - 30 JUL
08W TS BILL 07 AUG - 08 AUG
09W TS CLARA 10 AUG - 12 AUG
10W TY DOYLE 15 AUG - 21 AUG
11W TS ELSIE 28 AUG - 29 AUG
11W TS ELSIE* 31 AUG - 31 AUG
12W TY FABIAN 30 AUG - 03 SEP
13W TS GAY 02 SEP - 04 SEP
* REGENERATED
a = TY SUSAN
b = TS AGNES
c = TS GAY
E 100
110
120
130
140
150
160
170
180
170
160 W
N 50
40
30
20
10
EQ
S 5
TY FABIAN
TY DOYLE
TS AGNES
TS GAY
TS BILL
TS CLARA
TY THAD
TS CLARA
TS ELSIE
TY WARREN
TD 03W
TY DOYLF
TS VANESSA
TS BILL
TS ELSIE
TD 03W
TY ROY
TS VANESSA
TY WARREN,
TY THAD
TY ROY


NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
07 SEP 1988 - 31 DEC 1988
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
14W TY HAL 08 SEP - 17 SEP
01C TY ULEKI 28 AUG - 08 SEP
01C TY ULEKI 08 SEP - 13 SEP
15W TS IRMA 12 SEP - 15 SEP
16W TS JEFF 14 SEP - 16 SEP
17W TS KIT 19 SEP - 22 SEP
18W TS LEE 21 SEP - 24 SEP
19W TS MAMIE 22 SEP - 23 SEP
20W STY NELSON 01 OCT - 08 OCT
21W TY ODESSA 11 OCT - 16 OCT
22W TY PAT 18 OCT - 22 OCT
23W TY RUBY 21 OCT - 28 OCT
24W TY SKIP 03 NOV - 11 NOV
25W TY TESS 04 NOV - 06 NOV
26W TS VAL 22 DEC - 26 DEC
* CPHC WARNINGS
a = TS JEFF
b = TS KIT
c = TS MAMIE
d = TY ODESSA
e = TY RUBY
f = TY SKIP
g = TS TESS
h = TS VAL
E 100
110
120
130
140
150
160
170
180
170
160 W
N 50
40
30
20
10
EQ
S 5
TY HAL
STY NELSON
TY ULEKI
TS IRMA
TS LEE
TY ODESSA
TS JEFF
TS KIT
TY PAT
TS MAMIE
TY RUBY
TY SKIP
TY TESS
TS IRMA
TY HAL
TS LEE
STY NELSON
TY PAT
TS VAL
W 160
150
140 W
N 20
N 10
TY ULEKI


TYPHOON ROY
BEST TRACK TC-01W
05 JAN-18 JAN 88
MAX SFC WIND 115KT
MINIMUM SLP 927MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
DTG SPEED INTENSITY
16/0000Z 12 75
16/0600Z 12 65
16/1200Z 12 50
16/1800Z 11 40
17/0000Z 16 40
17/0600Z 13 35
17/1200Z 13 30
17/1800Z 11 25
18/0000Z 8 25
18/0600Z 9 25
L - 18/00Z
N 18
N 13
E 115
120
125 E
F - 08/00Z
TCFA
ABPW
E 125
130
135
140
145
150
155
160
165
170
175
180
N 40
35
30
25
20
15
10
5
EQ

TYPHOON ROY (01W)

Typhoon Roy was the first significant tropical cyclone of 1988 in the western North Pacific. It formed as a "twin" (Figure 3-01-1) with its southern hemisphere counterpart, Tropical Cyclone 07P (Anne). During a period of eleven days in January, Roy made a 4000 nm (7408 km) westward trek, caused significant damage on Kwajalein Atoll and the islands of Guam and Rota, crossed the Philippine Islands and dissipated over the South China Sea. Typhoon Roy's close approach to Guam resulted in the most destruction since Super

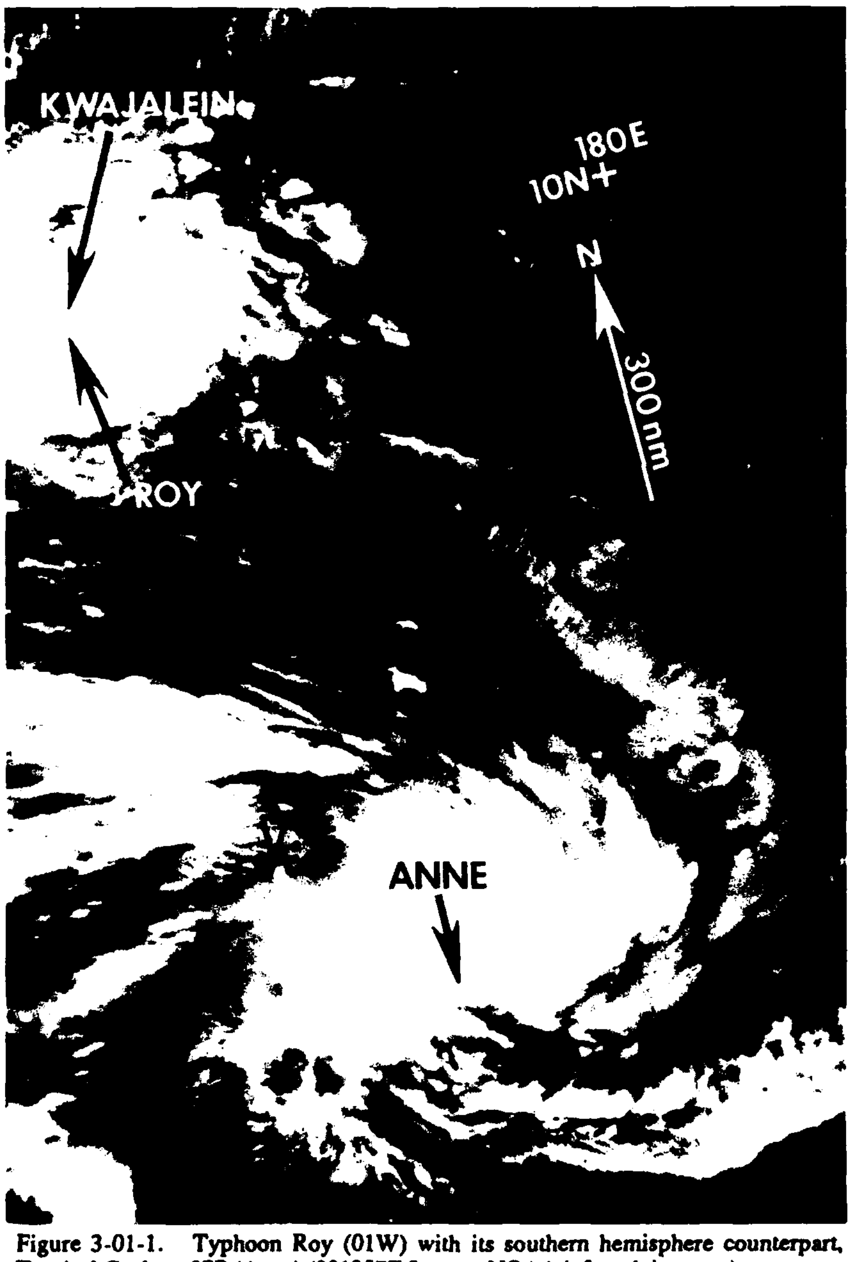


Figure 3-01-1. Typhoon Roy (01W) with its southern hemisphere counterpart, Tropical Cyclone 07P (Anne) (081957Z January NOAA infrared imagery).

Typhoon Pamela (1976).

Prior to tropical cyclone genesis, above normal sea surface temperature anomalies and greater than normal cloudiness persisted in the central Pacific Ocean. Roy began in this area of increased cloudiness southeast of the Marshall Islands, with persistent convection first noted on the Significant Tropical Weather Advisory at 060600Z. The suspect area was mirrored by another area of persistent convection in the southern hemisphere, which developed into Tropical Cyclone 07P (Anne). A band of anomalous low-level equatorial westerlies was located between the two cloud systems. Gradient-level wind reports from Tarawa (WMO 91610) in the Kiribati Islands during early January consistently indicated moderate westerly winds. (Climatic windflow at Tarawa for January is east-northeasterly at 12 kt (6 m/sec).)

By 7 January, Roy's cloud organization had improved and JTWC issued a Tropical Cyclone Formation Alert at 072000Z. Satellite intensity technique estimates of 30 kt (15 m/sec) combined with synoptic reports of 30 kt (15 m/sec) surface winds and a 997 mb surface pressure from Majuro (WMO 91376) prompted the issuance of the first warning on Tropical Depression 01W at 080000Z. (Tropical Cyclone 07P (Anne) in the southern hemisphere reached tropical storm intensity 12-hours earlier). As Tropical Depression 01W moved north of Majuro, the island experienced maximum sustained winds of 35 kt (18 m/sec) with gusts to 45 kt (23 m/sec), and several buildings suffered minor structural damage.

Satellite reconnaissance continued to detect deepening of the system and Tropical Depression 01W was upgraded to a tropical storm at 080600Z. Roy (Figure 3-01-1) passed 35 nm (65 km) south of Kwajalein Atoll at 081800Z. Kwajalein Island (WMO 91366) reported maximum sustained winds of 48 kt (25 m/sec) with a peak gust of 57 kt (29 m/sec), a minimum sea-level pressure (MSLP) of 992 mb and light-to-moderate structural damage. Ebeye

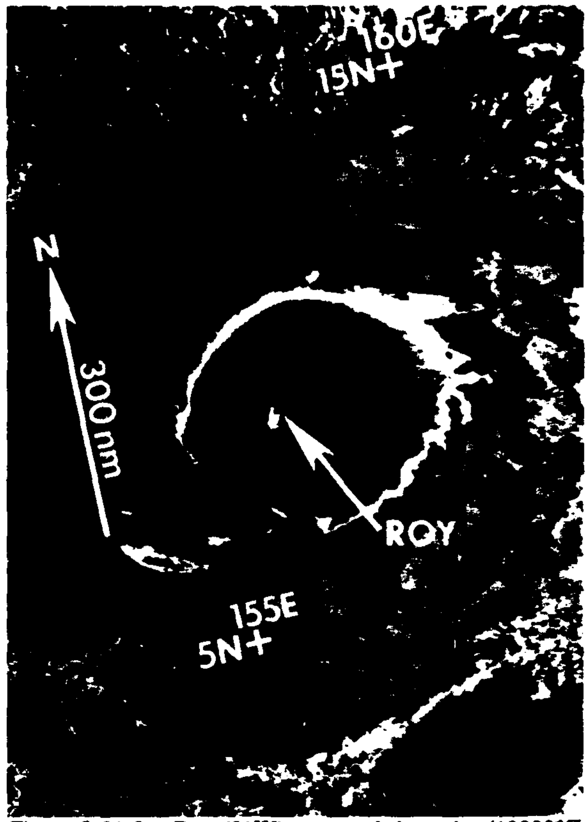


Figure 3-01-2. Roy (01W) near peak intensity (100823Z January DMSP enhanced infrared imagery).

Island just 4 nm (7 km) to the north experienced moderate-to-severe structural damage, one death and loss estimates of five million dollars. Both islands had 20 to 22 ft (6.1 to 6.7 m) surf and low-lying areas were flooded. Using their weather radar, meteorologists on Kwajalein were the first to detect the formation of Roy's eye at 081000Z. Later at 091200Z, a satellite estimate of 65 kt (33 m/sec) resulted in the upgrade to typhoon intensity.

While at a forward speed of 22 kt (41 km/hr) at 101200Z, Roy (Figure 3-01-2) reached a peak intensity of 115 kt (59 m/sec) 510 nm (945 km) east-southeast of Guam . The typhoon was embedded in a moderate mid-tropospheric east-southeasterly flow south of the subtropical ridge axis, as indicated by aircraft reports at 500 mb (Figure 3-01-3). Then Typhoon Roy slowed to 12 kt (22 km/hr) as it approached Guam (Figure 3-01-3). Detachment 2, 20 Weather

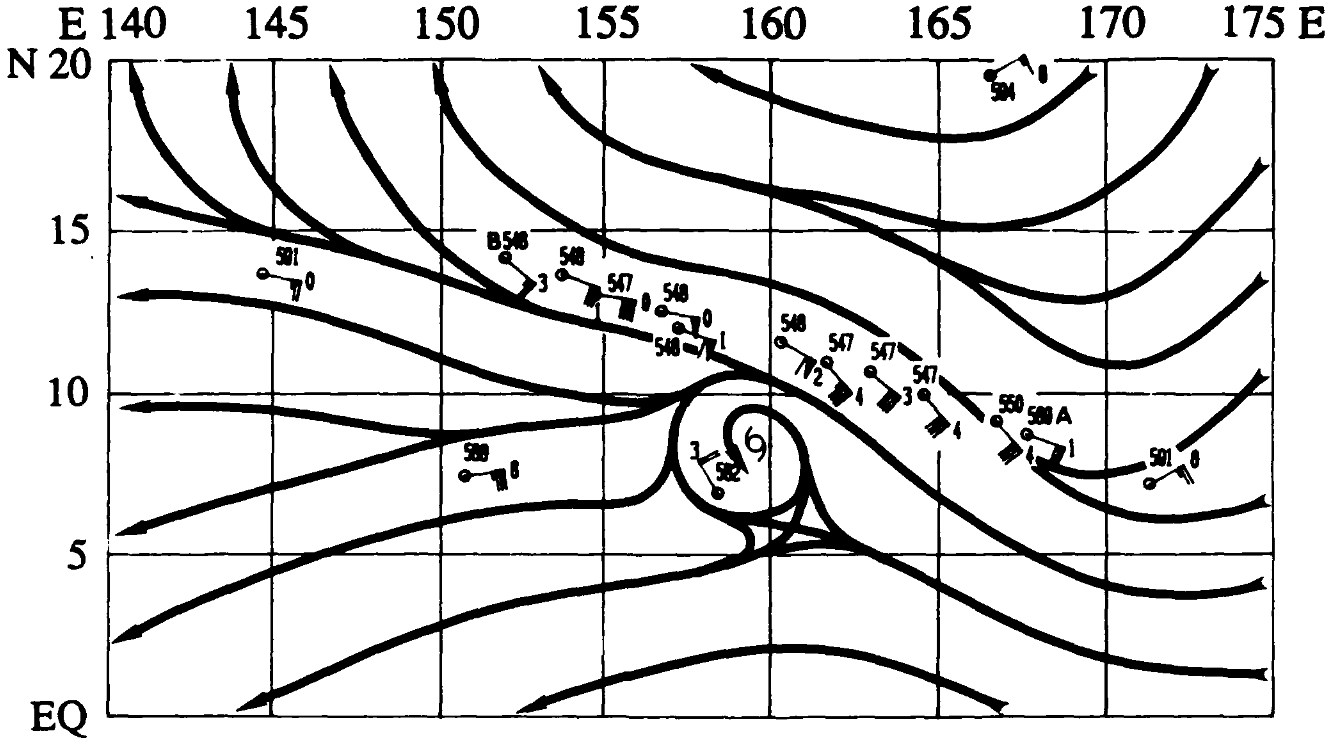


Figure 3-01-3. 100000Z January 500 mb streamline analysis with additional reports along the aircraft track to the north of Roy. The aircraft reports are from point A (100057Z) to point B (100340Z).

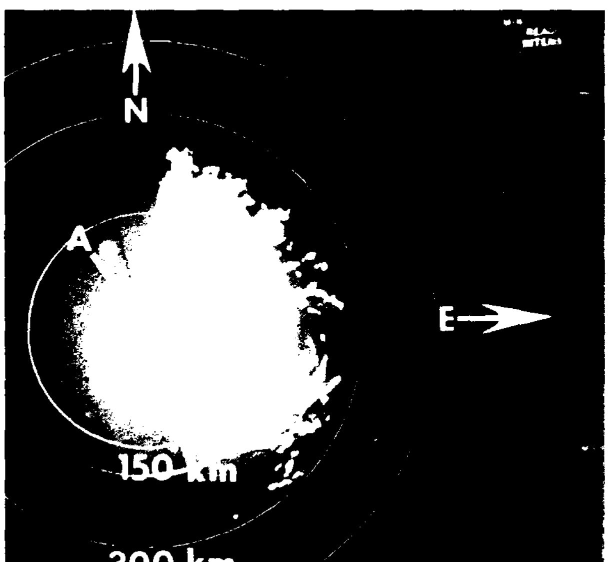


Figure 3-01-4. Spiral rainband echoes define the typhoon's eye at 112310Z January 120 nm (222 km) east-southeast of the radar site. The weather radar (at point A) is located at Andersen Air Force Base on the northeastern tip of Guam (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).

Figure 3-01-5. 110838Z January digitized radar display of Roy's rain shield. Note the island of Rota (call sign PGRO) lies within the ragged eye. The call sign PGUA marks the location of Andersen Air Force Base on Guam and PGSN the airfield on Saipan (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).

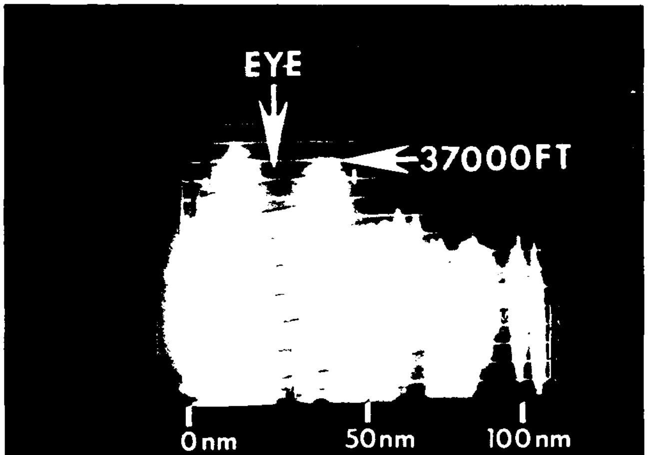


Figure 3-01-6. At 110838Z January the Andersen Air Force Base weather radar display paints 37,000 feet (11.3 km) rain echo tops in the outer eye wall cloud. The radar returns in the lower left of the picture and closest to the radar site are attenuated due to heavy rain (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).

Squadron at Andersen Air Force Base on Guam first detected the eye on radar at 111930Z (Figure 3-01-4). These weather radar data were instrumental in tracking Typhoon Roy's center, as it made its closest point of approach (Figures 3-01-5 and 3-01-6) 32 nm (59 km) north of Guam at 120930Z . Wind estimates near the center were 110 kt (57 m/sec). However, Andersen Air Force Base on the northeastern tip of Guam measured maximum sustained winds of 66 kt (34 m/sec) with peak gusts to 98 kt (50 m/sec) as the eye wall passed just to the north. Buildings, particularly those on the northern part of Guam, sustained light-to-moderate structural damage (Figure 3-01-7). Crops and vegetation on Guam suffered extensive damage, with estimates of losses as high as 23.5 million dollars. As a credit to the disaster preparedness team, no severe injuries or loss of life were


Figure 3-01-7. Roy almost went on a shopping spree as indicated by the structural damage to the Andersen Air Force Base commissary on Guam.

Figure 3-01-8. Strong winds rearranged these parked vehicles.

reported on Guam (Figure 3-01-8).

In comparison, the island of Rota, 40 nm (74 km) north-northeast of Guam, suffered the heaviest damage. At 120724Z, shortly before eye passage, Rota's automated weather observing equipment reported maximum sustained winds of 71 kt (37 m/sec) with peak gusts to 104 kt (54 m/sec). Because of apparent communication problems, no further data were received until the 120905Z report of 60 kt (31 m/sec) with gusts to 89 kt (46 m/sec). Residents of Rota described the eye passage as a marked lessening of wind speed and clearing skies from 120730Z to 120810Z. Concurrently, a microbarograph trace from the Naval Oceanography Command Detachment, Agana, located on central Guam indicated a minimum sea-level pressure of 979 mb from 120800Z to 121000Z (Figure 3-01-9). A large percentage of the homes on Rota were destroyed and the remainder damaged. Four minor injuries were reported, which resulted when a flying roof impacted another building where people had sought shelter. Numerous coconut trees were downed and all crops destroyed. With an estimated 95 percent of the utility poles knocked down, lack of power and potable water completely disrupted the community.

After moving through the southern Marianas, Roy continued to slow. Earlier analysis of 500 mb aircraft reports revealed a mid-tropospheric anticyclone east of the Philippine Islands with ridging extending to the northeast of Roy's center. As Typhoon Roy approached the Mariana Islands, it apparently responded to the weaker mid-level steering flow and decelerated. A weakness in the subtropical ridge was located almost due north of Guam . It was initially thought that Roy would weaken the subtropical ridge and ultimately recurve. However, this did not happen. Instead, the lower tropospheric ridge built, as reflected by 700 mb pressure-height rises at Iwo Jima (WMO 47971). In turn the typhoon accelerated to the southwest. (By this time, Roy's maximum sustained winds had weakened to 90 kt (46 m/sec). This intensity was maintained until reaching the mountainous terrain of southern Luzon.)

At 141800Z, Roy returned to a more westward course along the southern edge of the subtropical ridge and increased its speed of 20 kt (37 km/hr). From 160000Z to 170000Z, Roy tracked across southern Luzon. The mountains and increased vertical wind shear further

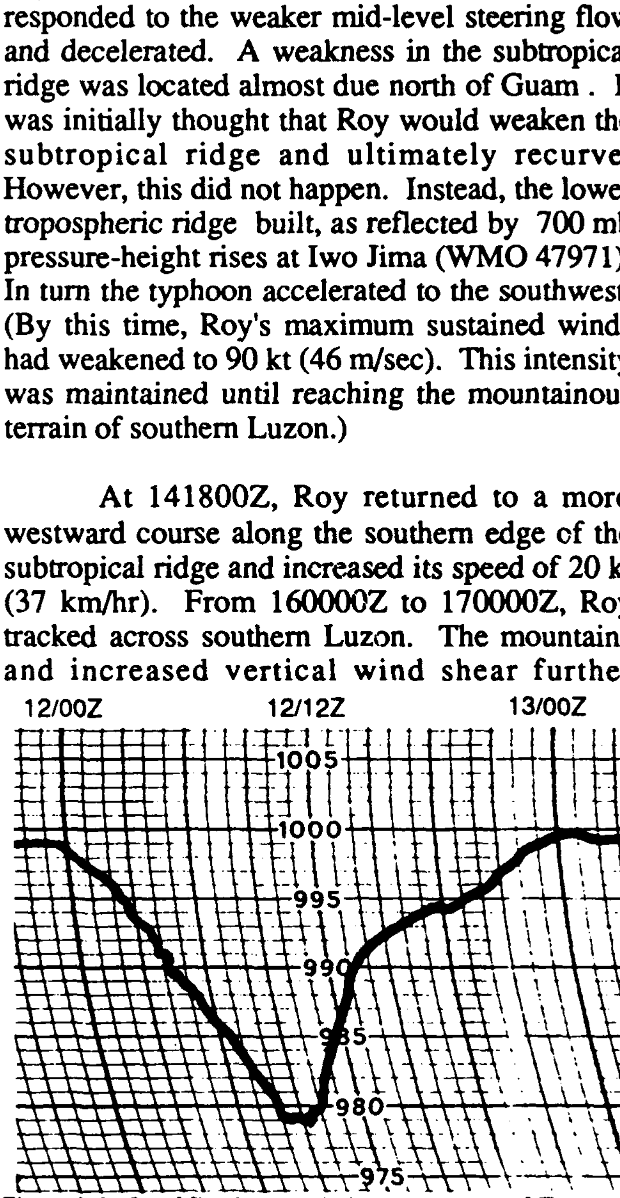
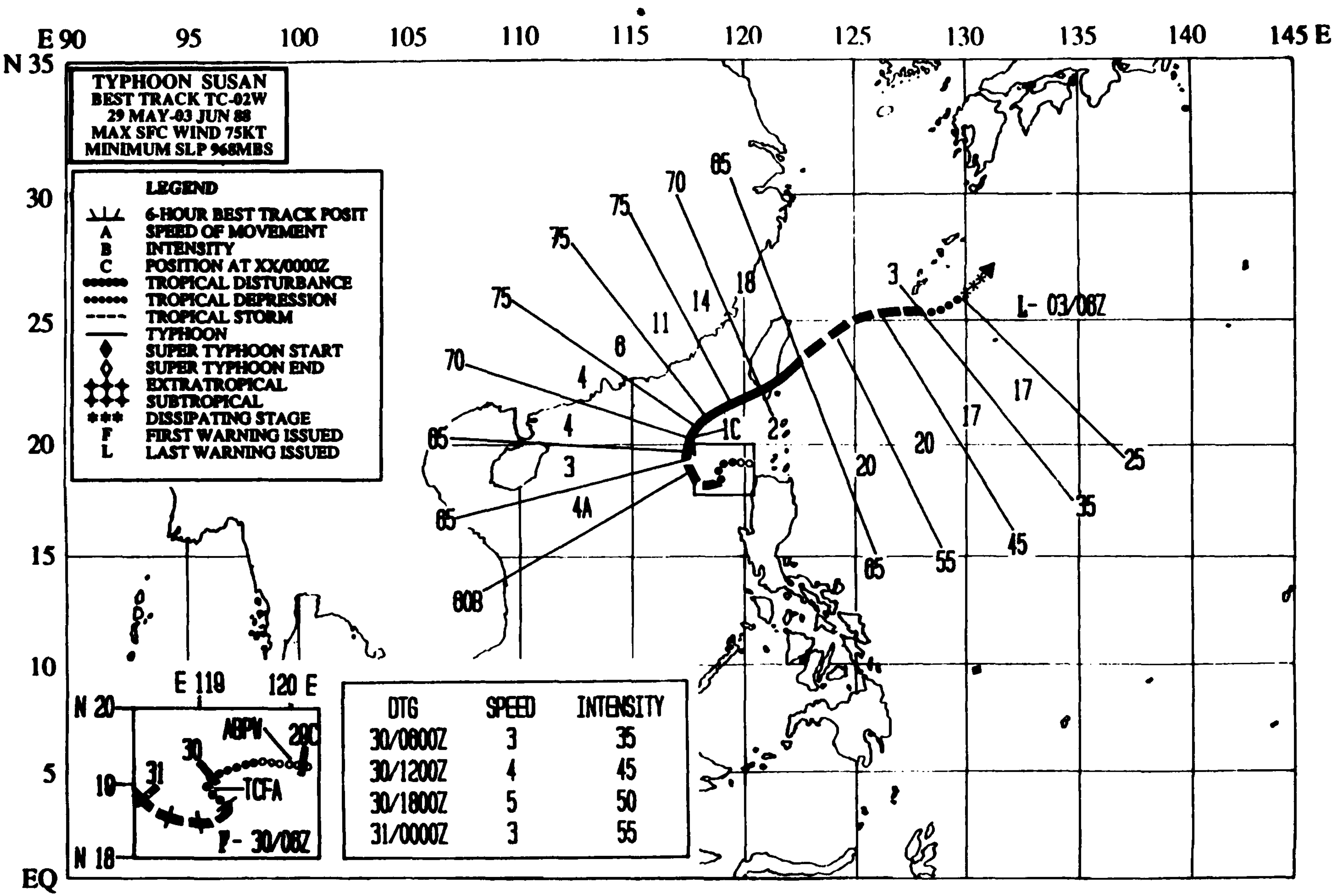


Figure 3-01-9. Microbarograph (pressure) trace of Typhoon Roy (01W) recorded at the Naval Oceanography Command Detachment, Agana, Guam indicates a minimum sea-level pressure of 979 mb from 120800Z to 121000Z January.

weakened Roy from 75 kt (39 m/sec) to 40 kt (21 m/sec). Once in the South China Sea, Roy's interaction with the low-level northeasterly flow of the winter monsoon spawned gales, but dissipation was imminent. At 171200Z, Tropical Storm Roy was downgraded to a tropical depression and the final warning followed at 180000Z.

Intentionally left blank


TYPHOON SUSAN
BEST TRACK TC-02W
29 MAY-03 JUN 88
MAX SFC WIND 75KT
MINIMUM SLP 968MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
DTG SPEED INTENSITY
30/0600Z 3 35
30/1200Z 4 45
30/1800Z 5 50
31/0000Z 3 55
L- 03/08Z
F- 30/08Z
ABPW
TCFA
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
E 119
120 E
N 20
N 18

TYPHOON SUSAN (02W)

Susan was a short-lived typhoon with maximum sustained winds of 75 kt (39 m/sec). Slow to exit the the South China Sea, it threatened the southeast of coast of China, then churned across the southern tip of Taiwan and rapidly weakened.

The synoptic pattern during the fourth week of May was anomalous with low-level southwesteries extending across the northern Philippine Sea into the northern Marianas and southern Bonin Islands (Figure 3-02-1). Surface pressures in the monsoonal trough, that was north of this southwesterly flow, were 4 to 5 mb below normal. Cyclonic vortices that formed in the trough were transitory until 28 May when a persistent circulation formed off the northwest coast of Luzon (see Figure 3-02-2). Initially the convection was displaced equatorward of the the low-level circulation center by vertical wind shear, but within a day the cloudiness became more centralized. The cloud system as a whole then appeared to isolate itself from the surrounding zone of maximum cloudiness. The Significant Tropical Weather Advisory was reissued at 290200Z May to include this suspect monsoon depression. Although the upper-level outflow was restricted in the north and west, the amount of central convection and organization continued to increase, prompting JTWC to issue a Tropical Cyclone Formation Alert at 300200Z May. The first warning on Tropical Storm Susan at 300600Z followed from a satellite

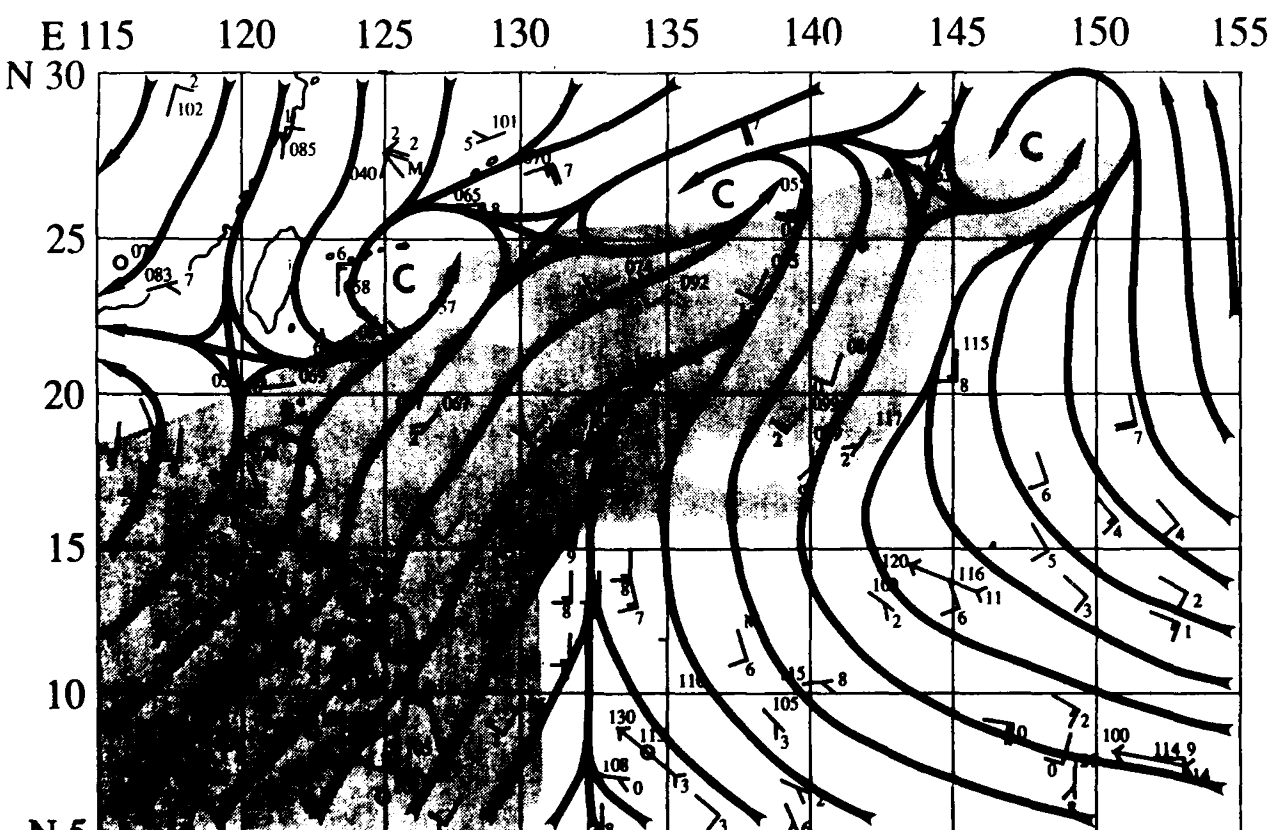


Figure 3-02-1. Surface/gradient analysis (260000Z May) shows the anomalous southwesterly flow extending eastward from the South China Sea.

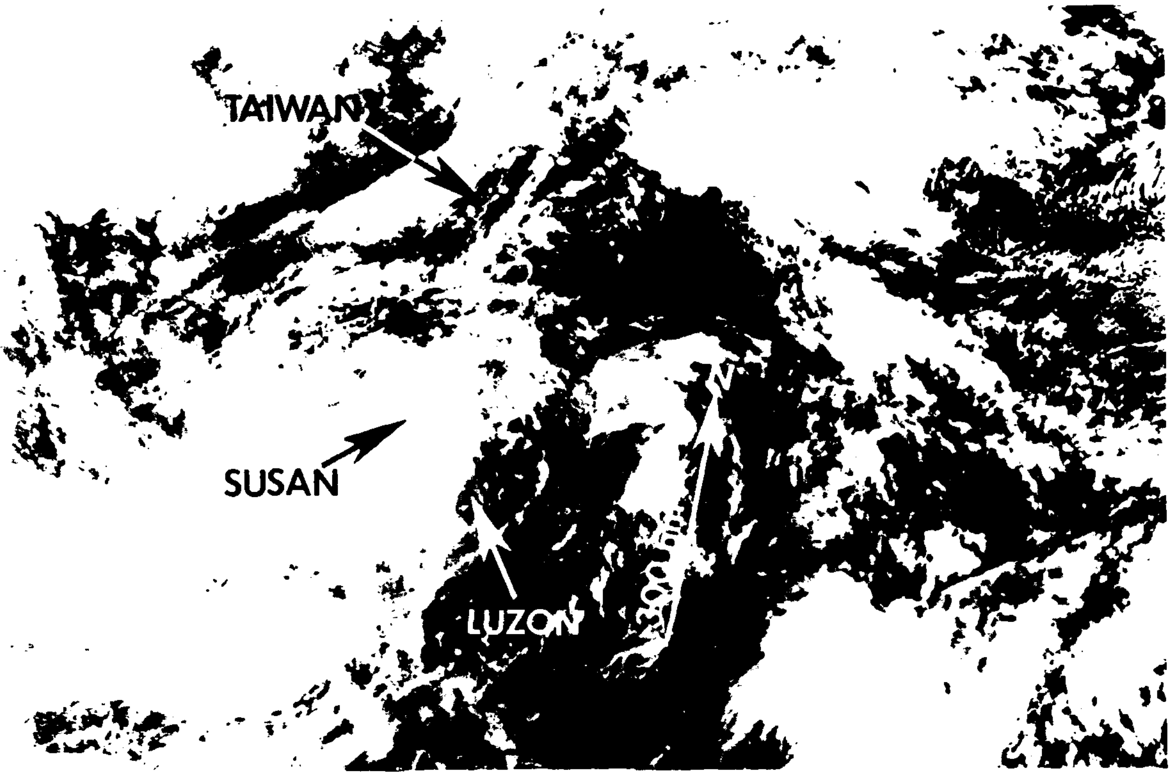


Figure 3-02-2. Susan as a tropical disturbance (280055Z May DMSP visual imagery).

analysis wind estimate of 45 kt (23 m/sec).

At warning time Susan's initial position was 65 nm (120 km) west of northern Luzon. Past movement had been erratic because the low-level circulation was located within the larger monsoonal trough. For forecast movement the tropical cyclone was near the axis of the subtropical ridge and recurvature was favored by the Typhoon Acceleration Prediction Technique (TAPT) (Weir, 1982). However, TAPT guidance identified the 200 mb northwesterly flow as unfavorable for rapid acceleration. The initial track forecasts were correct based on this guidance and Susan recurved and moved slowly to the northeast.

Susan intensified rapidly after recurvature. At 310600Z Susan was upgraded to a typhoon based upon satellite intensity estimates. The sustained winds increased to 75 kt (39 m/sec) at 010600Z June (see Figure 3-02-3). Now packing its most dangerous winds,

Figure 3-02-3. Typhoon Susan at maximum intensity in the Luzon Strait (011109Z June DMSP infrared imagery).

Susan accelerated towards the northeast and the southern tip of Taiwan. Aloft, a mid-level trough in the polar westerlies was advancing across eastern China. The trough became more meridional as it approached Susan. A combination of acceleration along-track, terrain effects (induced by the rugged mountains of Taiwan) and increasing vertical shear stripped away Susan's deep central convection, leaving behind an exposed low-level circulation center (Figure 3-02-4). The typhoon was downgraded to tropical storm intensity at 021200Z and further to a tropical depression at 030000Z. The final warning was issued at 030600Z. Twelve hours later the residual low-level vortex was no longer discernible on satellite imagery or in the synoptic data.

In retrospect, the majority of the damage to the island of Luzon, Republic of the Philippines resulted from heavy rains, not winds. A landslide triggered by these rains in Olongapo City, 50 nm (93 km) northwest of Manila, led to one death. In Manila another landslide killed five people. Flooding closed the main roads in Manila, disrupted travel and caused the loss of millions of prawns and lobsters from fishponds. Also, a tornado destroyed 18 homes outside of Manila.

Although Susan passed about 10 nm (18 km) south of the island of Okinawa, Japan at 022200Z, the system had rapidly weakened and the peak wind recorded at Kadena Air Base was 41 kt (21 m/sec) with 47 kt (24 m/sec) at Naha. No deaths or injuries were reported by authorities on Okinawa. No reports of damage were received from Taiwan.

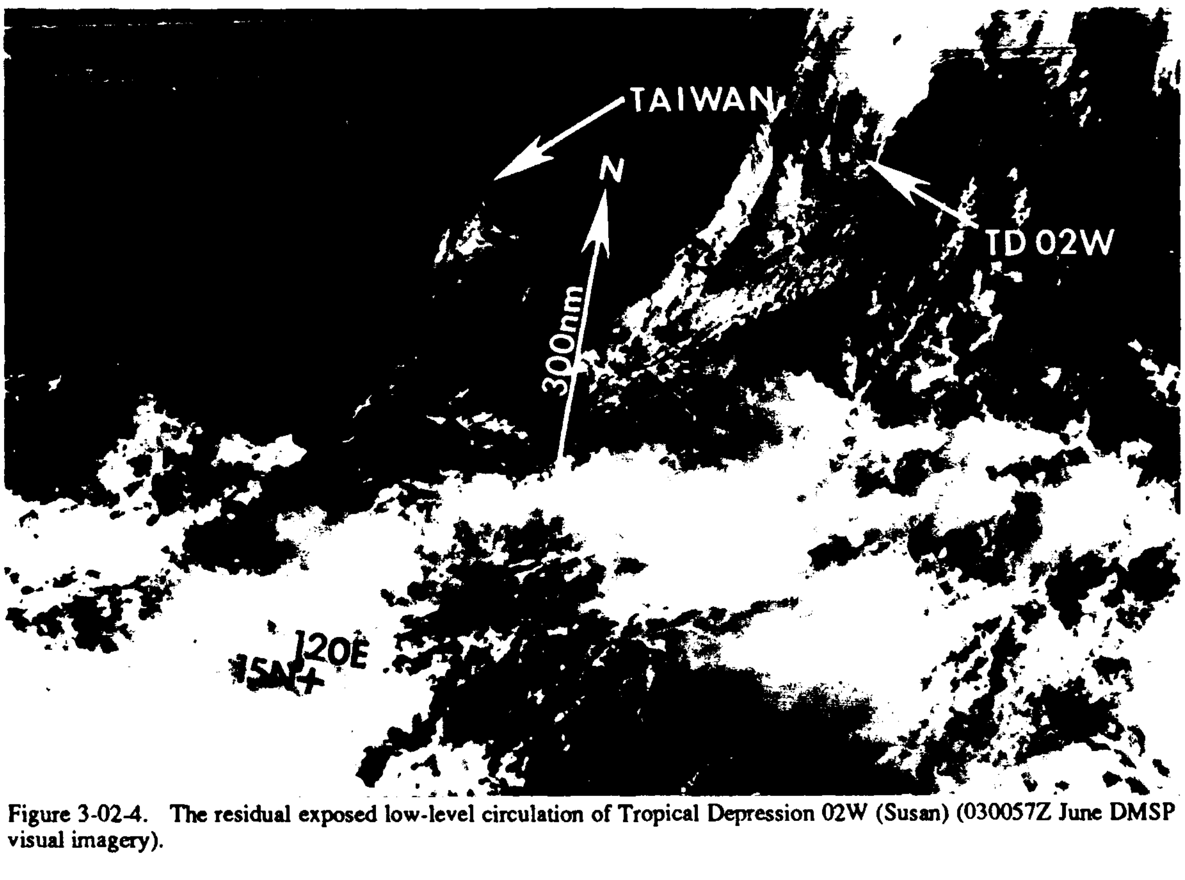
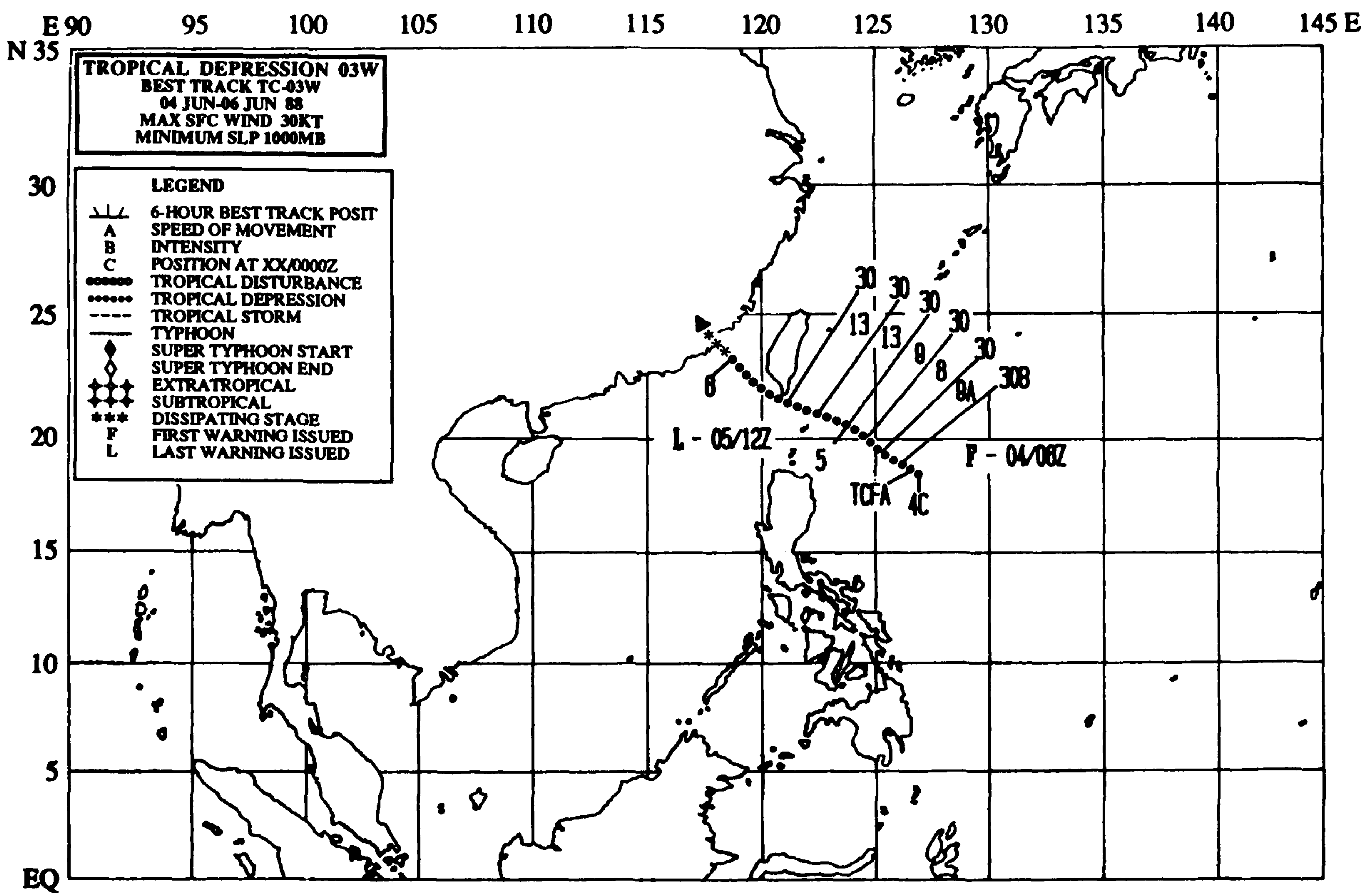


Figure 3-02-4. The residual exposed low-level circulation of Tropical Depression 02W (Susan) (030057Z June DMSP visual imagery).



TROPICAL DEPRESSION 03W
BEST TRACK TC-03W
04 JUN-06 JUN 88
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
L - 05/12Z
F - 04/06Z
TCFA
4C
30B
8A

TROPICAL DEPRESSION 03W

On 3 June the remains of Typhoon Susan (02W) sped northeastward and left behind the low-level southwest monsoonal flow which terminated abruptly in the northwestern Philippine Sea. Within a day the enhanced convection in the northwestern Philippine Sea acquired convective banding and cyclonic rotation. A Tropical Cyclone Formation Alert documented this event at 040200Z. The convection consolidated near the low-level circulation center and the first warning on Tropical Depression 03W followed at 040600Z based on a satellite intensity estimate of 30 kt (15 m/sec) surface winds. The satellite imagery (Figure 3-03-1) shows Tropical Depression 03W near its maximum intensity of 30 kt (15 m/sec).

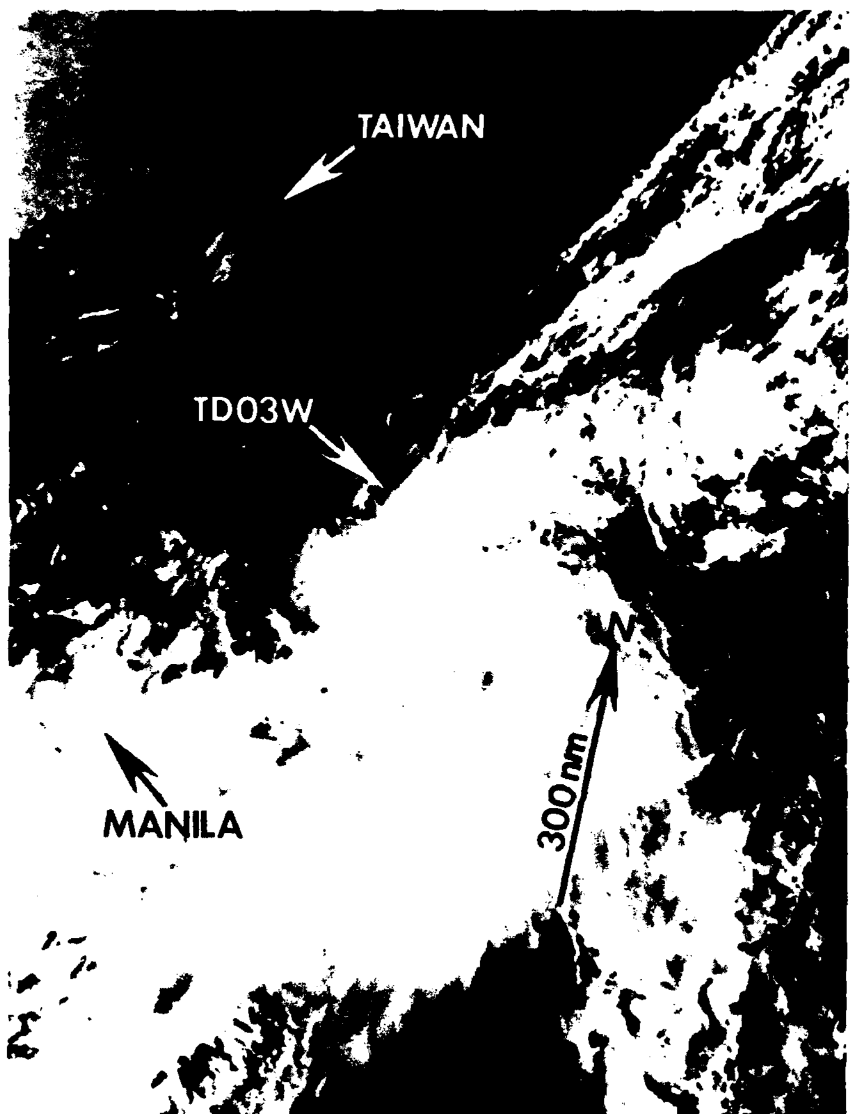


Figure 3-03-1. Tropical Depression 03W near peak intensity (040037Z June DMSP visual data).

Shortly after the first warning was issued, the central convection collapsed and further intensification ceased. In Figure 3-03-2 note that the system center is basically free of deep convection with only remnants of high cloud debris evident. The banding feature is displaced to the south and east. The next daytime visual imagery (Figure 3-03-3) reveals low-level stratiform cloudiness filling the center. The deep convection is well removed from the center with the exception of one transitory cumulonimbus. The final warning was issued on 051200Z June, when it became apparent that the system was dissipating.

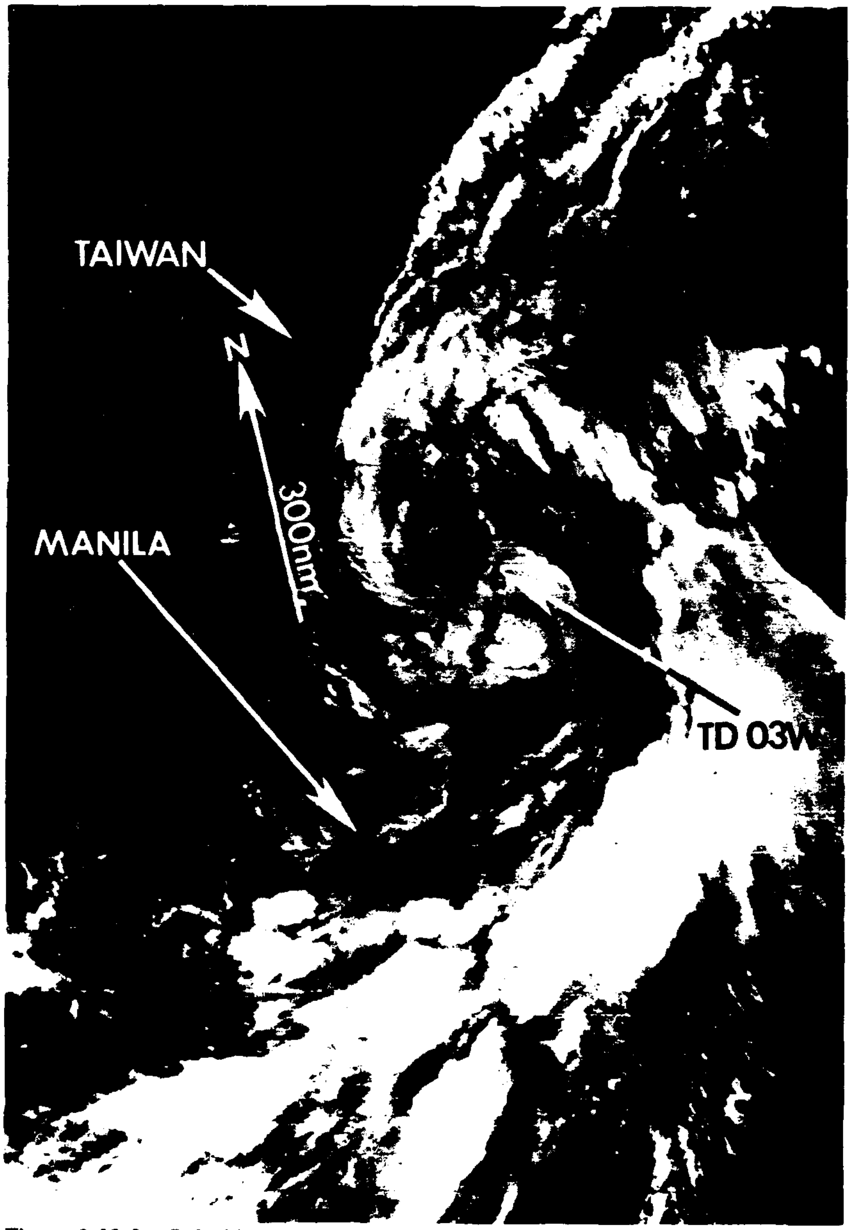
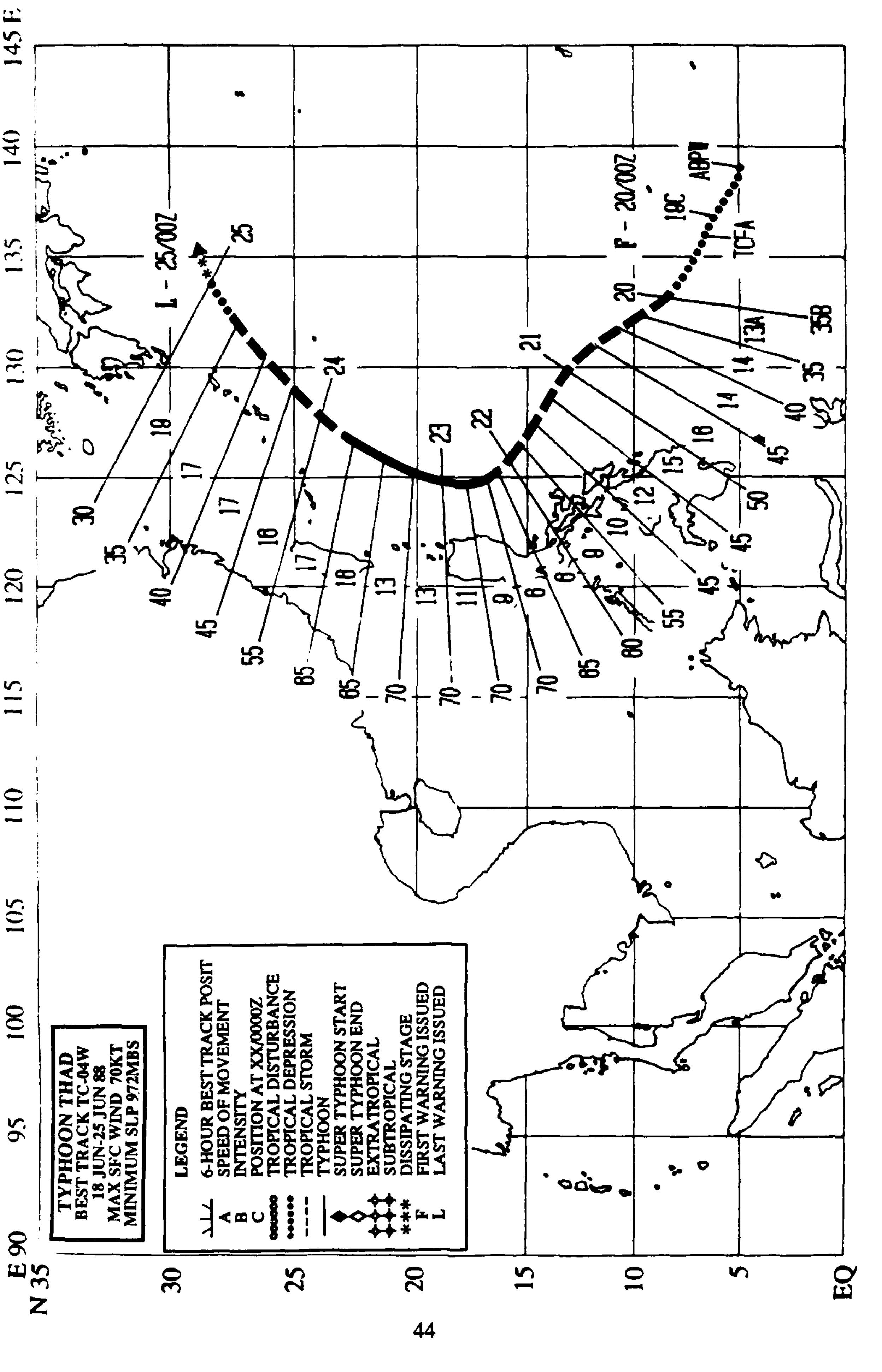


Figure 3-03-2. Only high-level cloud debris are in evidence over the center of the low-level circulation (041318Z June DMSP infrared imagery).

In retrospect Tropical Depression 03W's failure to mature and achieve tropical storm intensity may be related to its track. In contrast to Typhoon Susan (02W), which traveled northeastward along a zone of increased cloudiness, Tropical Depression 03W took a west-northwesterly track into the cloud minimum area that had settled across southeastern China and the northern South China Sea. Bao (1981) developed a hypothesis for forecasting typhoon movement based on satellite observed cloudiness which suggested that tropical cyclones move into, or along, areas of preexisting enhanced cloudiness - or conversely, tropical cyclones don't move into areas of minimum cloudiness. If they do, there is a price. Unless the tropical cyclone is large enough to modify the ambient environment, which is unfavorable, dissipation will result.

Figure 3-03-3. Stratiform low-level cloudiness fills the center of TD 03W (042302Z June NOAA visual imagery).



TYPHOON THAD
BEST TRACK TC-04W
18 JUN-25 JUN 88
MAX SFC WIND 70KT
MINIMUM SLP 972MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 25/00Z
F - 20/00Z
ABPW
TCFA
18C
13A
35B

TYPHOON THAD (04W)

Thad was the second of three tropical cyclones to develop during June and the third typhoon of 1988. Typhoon Thad tracked over 2000 nm (3704 km) during its lifetime, recurved just east of the island of Luzon in the Republic of the Philippines and passed 80 nm (148 km) southeast of the island of Okinawa, Japan before dissipating over water. The recurvature forecast was complicated by a complex interaction of the tropical cyclone with upper-level synoptic features.

After Tropical Depression 03W dissipated during the first week of June, there was a two week hiatus in tropical cyclone activity in the western North Pacific and low-level westerly flow established itself across the southern Philippine Sea. Thad began in the zone of increased cyclonic shear between this westerly flow and the easterly tradewinds 300 nm (556 km) south of Ulithi Atoll in the western Caroline Islands. The disturbance was first mentioned on the Significant Tropical Weather Advisory at 180600Z. Initially Thad's intensification may have been slowed by increased upper-level wind shear across the system, caused by the unfavorable location of an intense Tropical Upper-Tropospheric Trough (TUTT) low to its northeast. However, as the disturbance's central convection consolidated, the separation between Thad's upper-level circulation center and the TUTT low lessened.

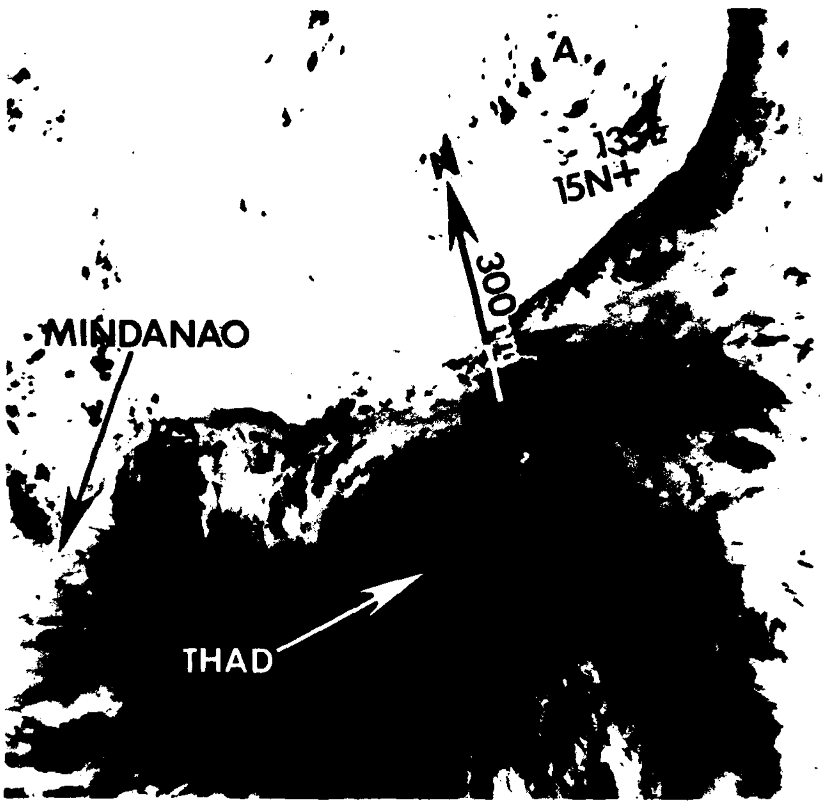


Figure 3-04-1. Thad, shortly before reaching tropical storm intensity. Note the vigorous TUTT cell (at A) to the northeast of the tropical disturbance (191914Z June NOAA infrared imagery).

The system's upper-level outflow pattern improved and a Tropical Cyclone Formation Alert followed at 190800Z (Figure 3-04-1). At 200000Z, satellite intensity analysis indicated a T-number of 2.5, corresponding to maximum sustained surface winds of 35 kt (18 m/sec) (Figure 3-04-2) and the Alert was upgraded to Tropical Storm Thad.

Throughout this period of gradual intensification, Thad was embedded in the flow south of the lower tropospheric subtropical ridge axis and moved northwestward, except for one excursion - the "stair-step" jog in the track from 200000Z to 201800Z. Afterward, Thad continued to track northwestward, intensifying for two more days, until reaching

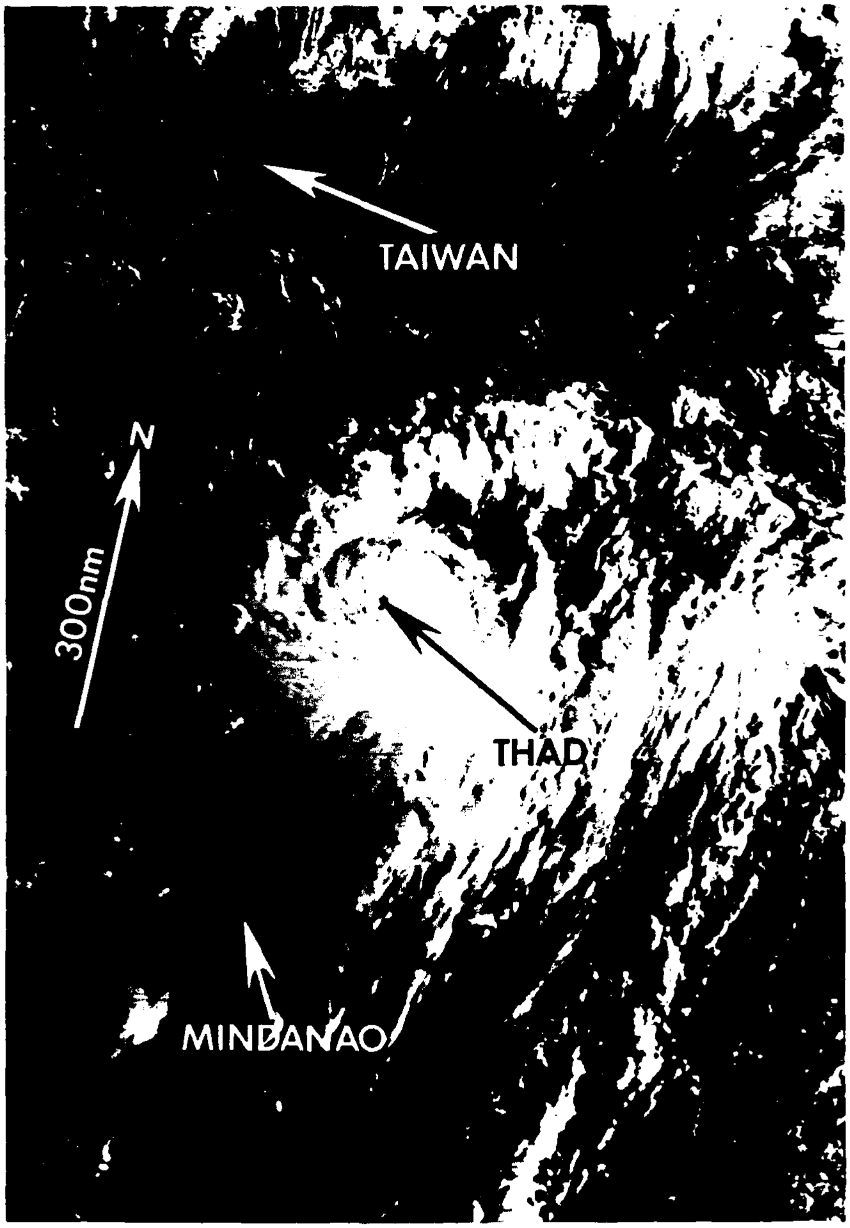


Figure 3-04-2. Thad intensifies as it approaches the island of Luzon (212128Z June NOAA visual imagery).

the westernmost end of the subtropical ridge where it began to recurve at 221800Z. The system reached its peak intensity and was upgraded to typhoon intensity at 220600Z, based on a satellite intensity estimate of 70 kt (36 m/sec) (Figure 3-04-3). Thad then developed a central cold cover (Dvorak, 1984) and further development was arrested.

At 221800Z, Typhoon Thad recurved in response to the approaching mid-level trough in the westerlies aloft over eastern China. The forecast for this event was complicated by the failure of JTWC's dynamic forecast aid, the One Way (Interactive) Tropical Cyclone Model (OTCM), to change from a persistent northwestward track (Figure 3-04-3). At 231200Z, the decision was made to disregard the objective forecast guidance and forecast recurvature based on synoptic data analyses. This decision was correct, but in retrospect, the timing was 18-hours late.

From 240000Z to 250000Z, Thad underwent rapid weakening as it tracked to the northeast and entered a region of increased vertical wind shear. At 240000Z, Typhoon Thad was downgraded to tropical storm intensity and six hours later the system weakened to a 50 kt (26 m/sec) intensity as it made a closest point of approach of 80 nm (148 km) southeast of the island of Okinawa, Japan. Both Kadena Air Base and Naha airport reported wind speeds below 30 kt (15 m/sec) during Thad's passage. With dissipation over water underway, Thad was downgraded to a tropical depression at 250000Z and the final warning issued. No reports of damage were received.

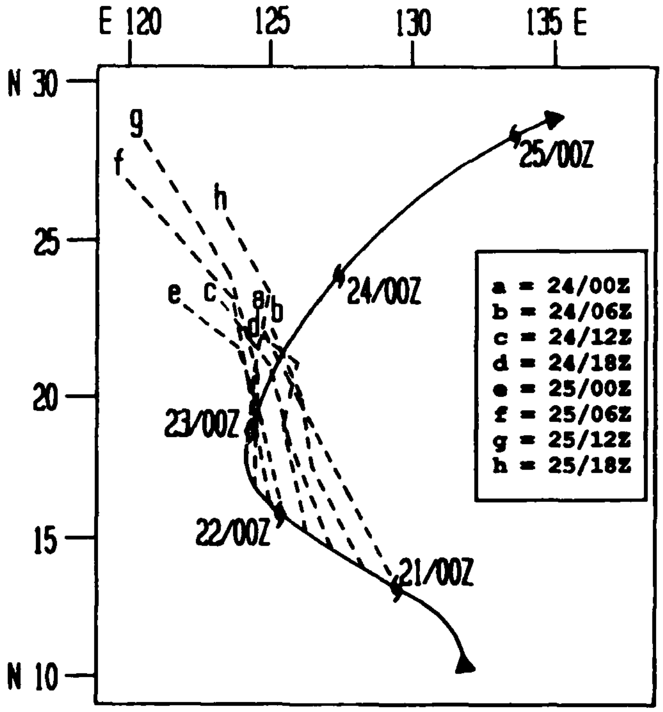
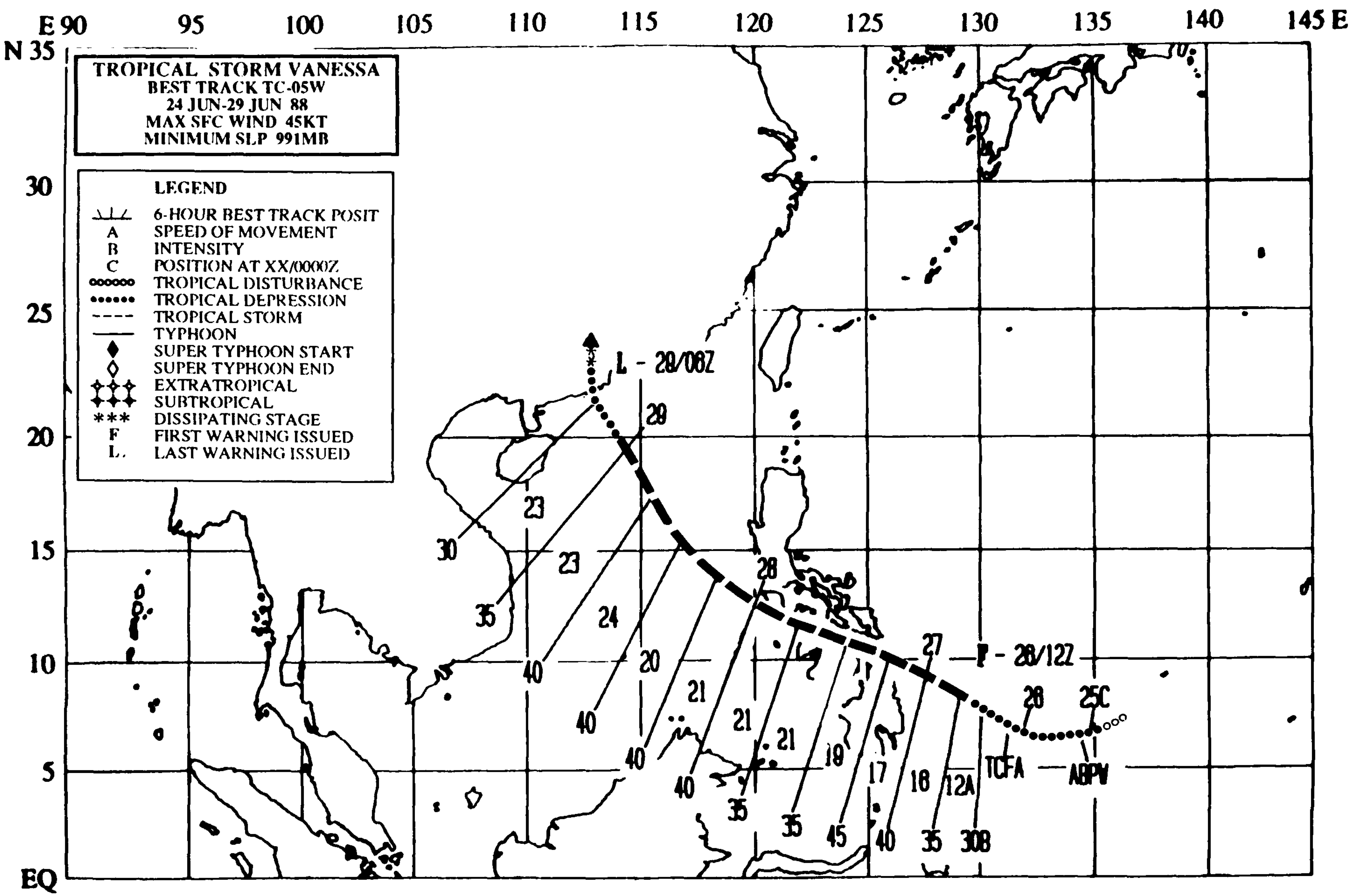


Figure 3-04-3. OTCM forecast guidance (dashed lines) from 210000Z to the point of recurvature at 221800Z basically held Thad to a northwestward track through each 72-hour period, in contrast to the best track (solid line).


TROPICAL STORM VANESSA
BEST TRACK TC-05W
24 JUN-29 JUN 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
L - 28/08Z
F - 26/12Z
TCFA
ABPW
25C
28
12A
30B

TROPICAL STORM VANESSA (05W)

The third of three significant tropical cyclones to develop during the month of June, Vanessa was the first "straight-runner" of the year in the western North Pacific. It tracked across the Philippine Islands and into the South China Sea before dissipating over southern China.

As Thad (04W) moved northeastward and weakened over the Philippine Sea east of the island of Okinawa, Vanessa was first detected at 241200Z by satellite imagery analysts 125 nm (232 km) east of Koror in the western Caroline Islands. A flare-up of convection at 241800Z resulted in an increase in high clouds. The upper-level outflow began to show organization (Figure 3-05-1). At 250600Z, the tropical disturbance was described on JTWC's Significant Tropical Weather Advisory as an area of persistent convection 55 nm (102 km) southeast of Koror. Synoptic data indicated a well organized low-level circulation embedded in the near-equatorial trough. Satellite imagery revealed a Tropical Upper-Tropospheric Trough (TUTT) low located 250 nm (463 km) northeast of the disturbance's low-level circulation. The upper-level cold low interrupted the disturbance's upper-level outflow in its northeast quadrant. At 260440Z, a Tropical Cyclone Formation Alert was issued when satellite imagery revealed increased convection. The TUTT low had weakened and passed north of the low-level circulation, resulting in divergent upper-level flow across the disturbance.

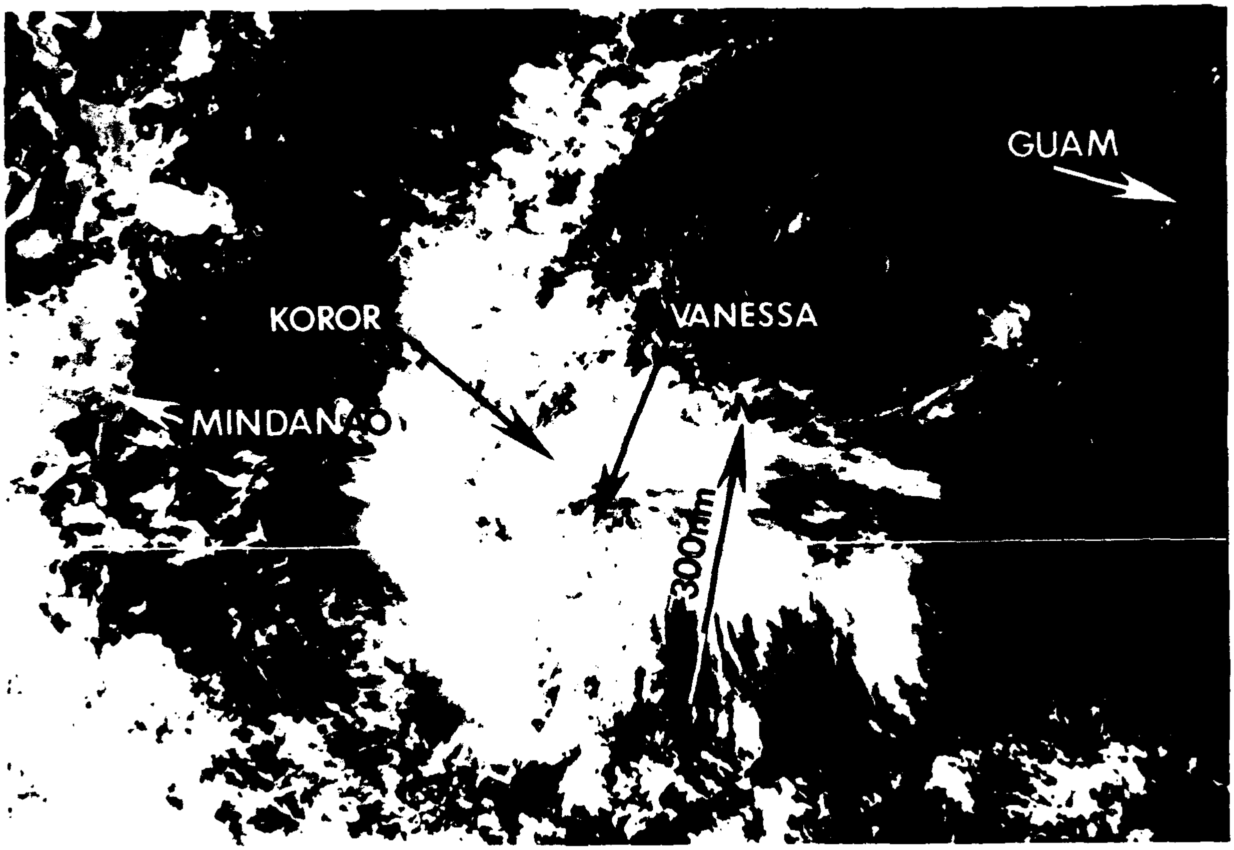


Figure 3-05-1. Vanessa as a tropical disturbance (250028Z June DMSP visual imagery).

The first warning followed at 261200Z, when the tropical disturbance was upgraded to Tropical Depression 05W, based on continued improvement in the system's organization and convection. Satellite intensity analysis indicated surface wind speeds of 30 to 35 kt (15 to 18 m/sec). The system continued to intensify. At 270000Z, Vanessa (Figure 3-05-2) was again upgraded, this time to a tropical storm, based on a satellite intensity analysis of 35 kt (18 m/sec) surface winds. With winds of 45 kt (28 m/sec), Vanessa made landfall over the Republic of the Philippines, at 270600Z, between the islands of Samar and Mindanao.

The tropical cyclone tracked rapidly across the central Philippine Islands, as a weak tropical storm, and entered the South China Sea at 280200Z. Vanessa continued its rapid movement as it tracked across the South China

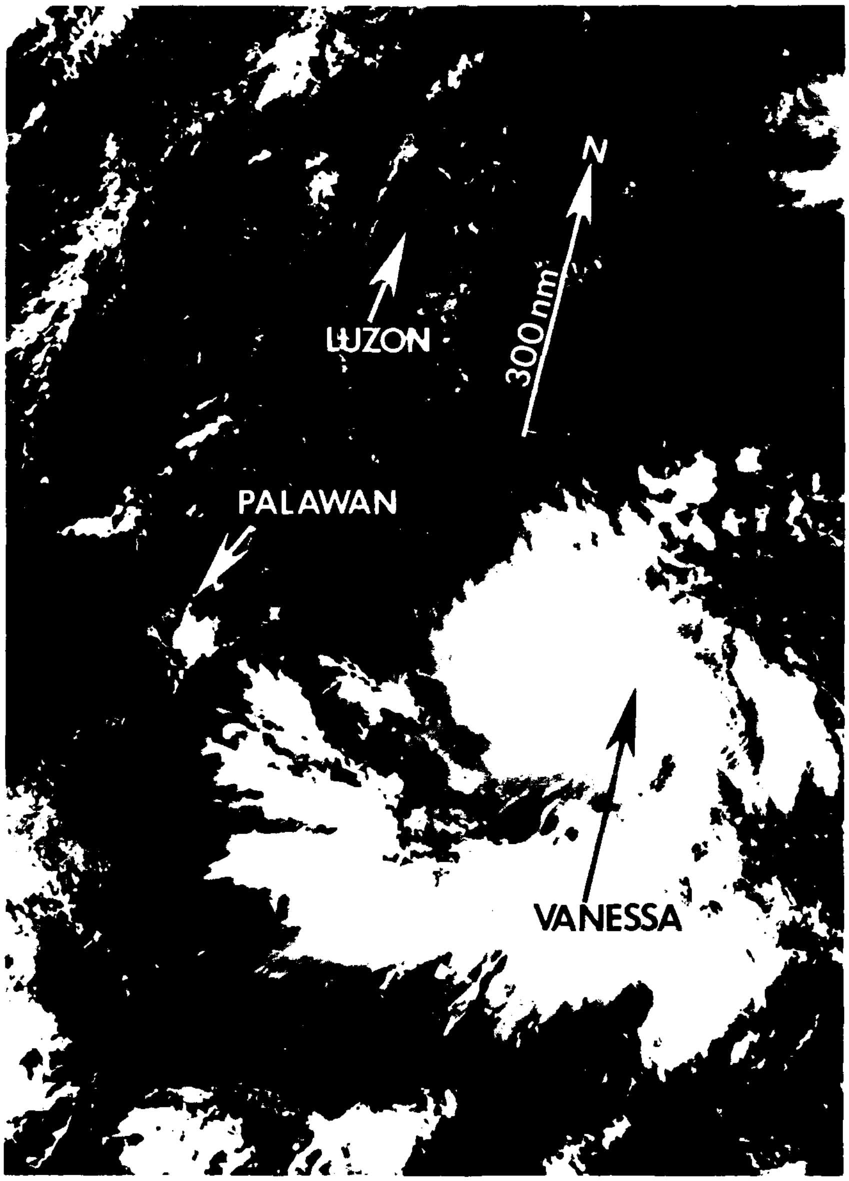


Figure 3-05-2. Nearing peak intensity, Vanessa approaches the central Philippine Islands (270130Z June DMSP visual imagery).

Sea. Despite increased vertical wind shear, Vanessa tenaciously resisted weakening until 290000Z. Over the next six hours, the deep convection was stripped away from the low-level circulation center (Figure 3-05-3) and the final warning followed at 290600Z. Vanessa made landfall just west of Macao on the south coast of China at 290800Z. Nearby land stations reported 35 kt (18 m/sec) maximum surface winds. No reports of major damage were received.

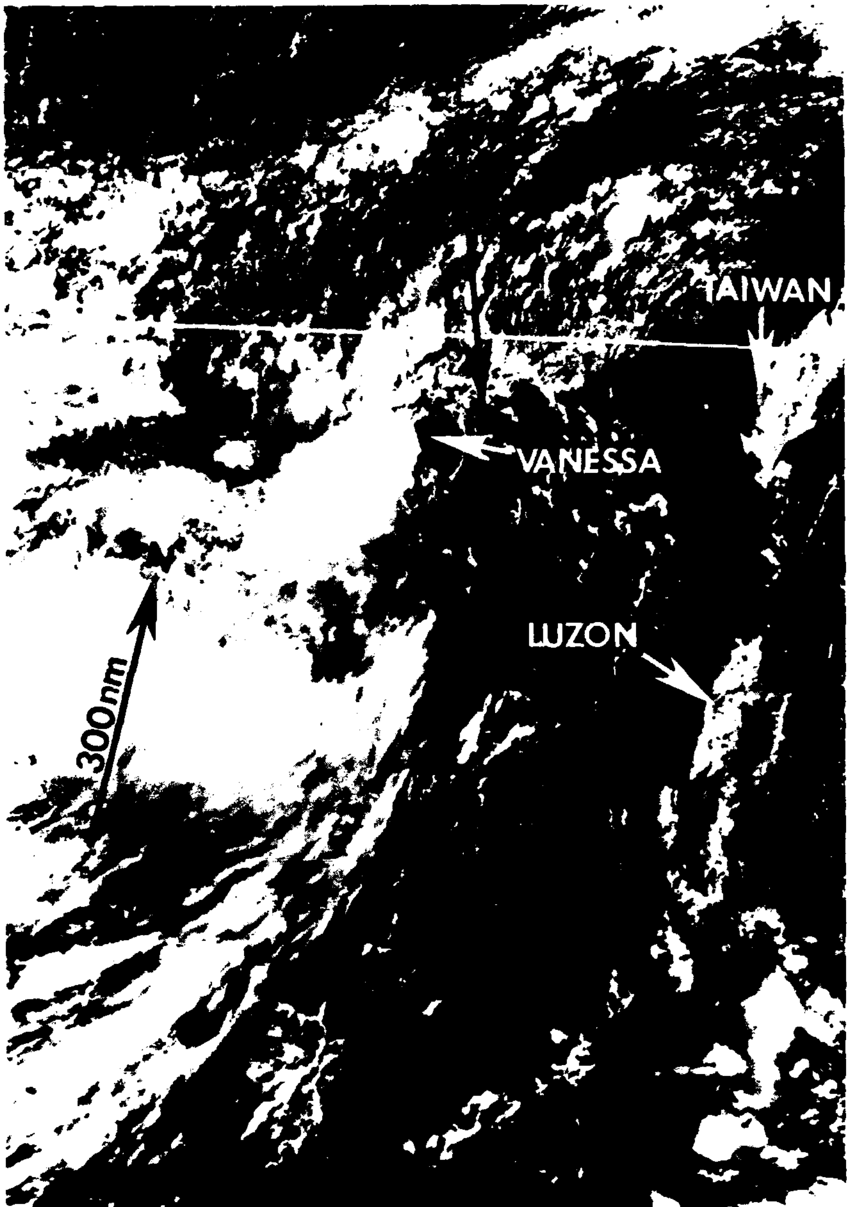
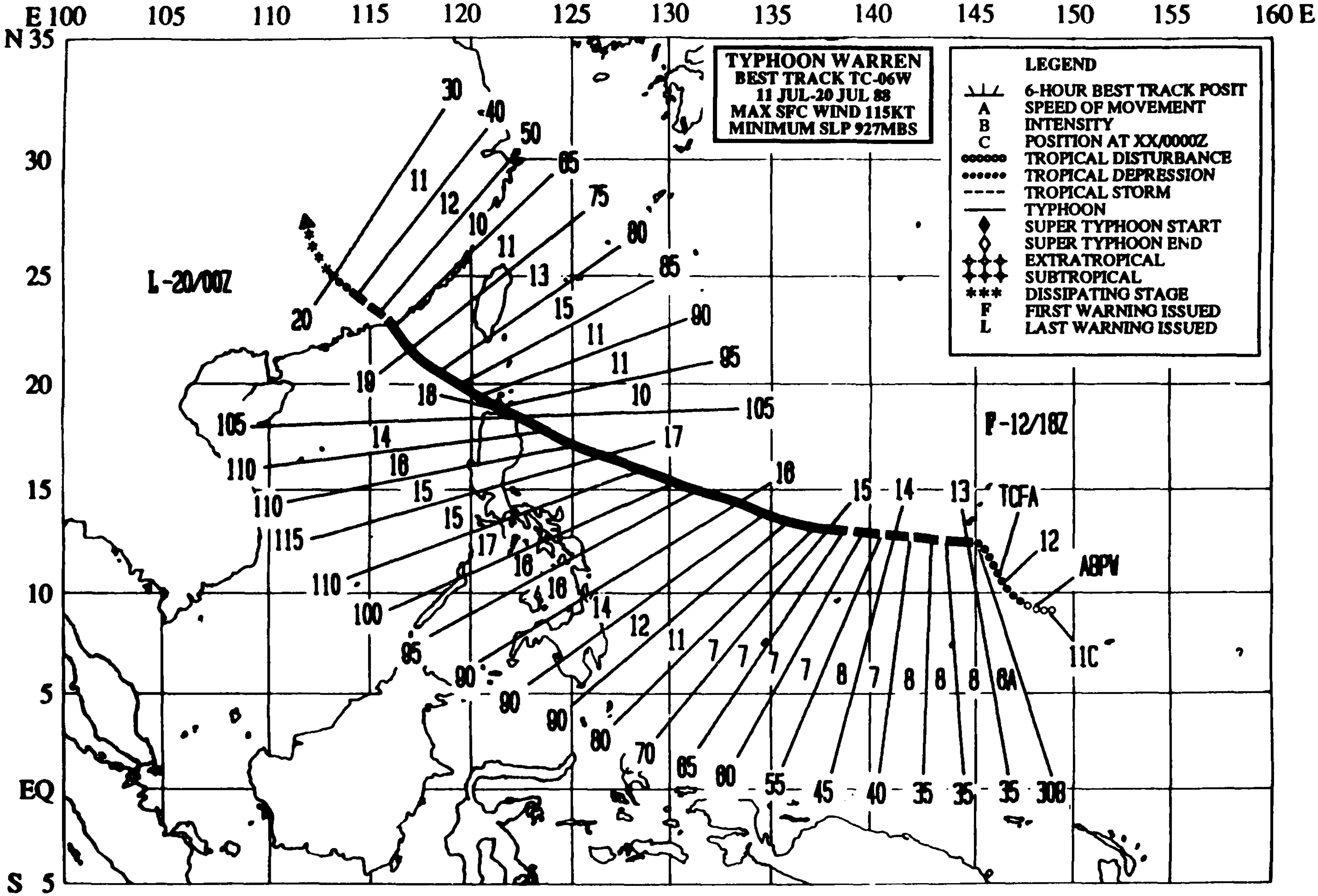


Figure 3-05-3. Vanessa's exposed low-level circulation, shortly before the system made landfall near Macao (290802Z June NOAA visual imagery).


TYPHOON WARREN
BEST TRACK TC-06W
11 JUL-20 JUL 88
MAX SFC WIND 115KT
MINIMUM SLP 927MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-20/00Z
F-12/18Z
TCFA
ABPW
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ
S 5

TYPHOON WARREN (06W)

Typhoon Warren was the first of two significant tropical cyclones to develop during the month of July, and the fourth tropical cyclone of the year to reach typhoon intensity. Warren was a "straight-runner" and maintained a west-northwestward direction of movement during almost its entire life span.

The tropical disturbance that eventually developed into Typhoon Warren was first mentioned on the Significant Tropical Weather Advisory at 110600Z. The suspect area had persisted as a poorly organized area of convection for 12-hours in the eastern Caroline Islands. Its potential for further development was assessed as "poor." However, better convective organization and improved upper-level outflow raised the potential for development into a significant tropical cyclone to "fair" and JTWC reissued the Advisory at 111230Z. Increased convection prompted a Tropical Cyclone Formation Alert at 120530Z. The system was now 180 nm (333 km) southeast of Guam and headed for the island. Satellite intensity analysis estimated sustained surface winds of 25 kt (13 m/sec).

The appearance of a central dense overcast (CDO) on the 121237Z satellite imagery led the satellite analyst to increase the intensity estimate of surface winds to 30 kt (15 m/sec). From 121200Z to 121500Z, the system's CDO increased in size. Because of the disturbance's steady development and its proximity to Guam, JTWC issued an abbreviated warning for the tropical depression at 121600Z: the detailed warning followed at 121800Z. The center of the system passed 55 nm (102 km) to the south of Guam at 130000Z.

After returning to a more westerly track, Tropical Depression 06W was upgraded to Tropical Storm Warren at 130600Z. (Post-analysis showed that Warren probably attained tropical storm intensity earlier at 130000Z.) At 141800Z, Warren reached typhoon intensity. This intensification process continued and peaked at 115 kt (58 m/sec) in the Philippine Sea 300 nm (556 km) east of Luzon (Figure 3-06-1). During this same two day period as the winds doubled in intensity, Warren also doubled its forward speed to 15 kt (28 km/hr).

While Warren tracked across the Philippine Sea, the One Way (Interactive) Tropical Cyclone Model (OTCM) outlook began to take the track northward into the

Figure 3-06-1. Typhoon Warren at peak intensity (162247Z July NOAA infrared imagery).

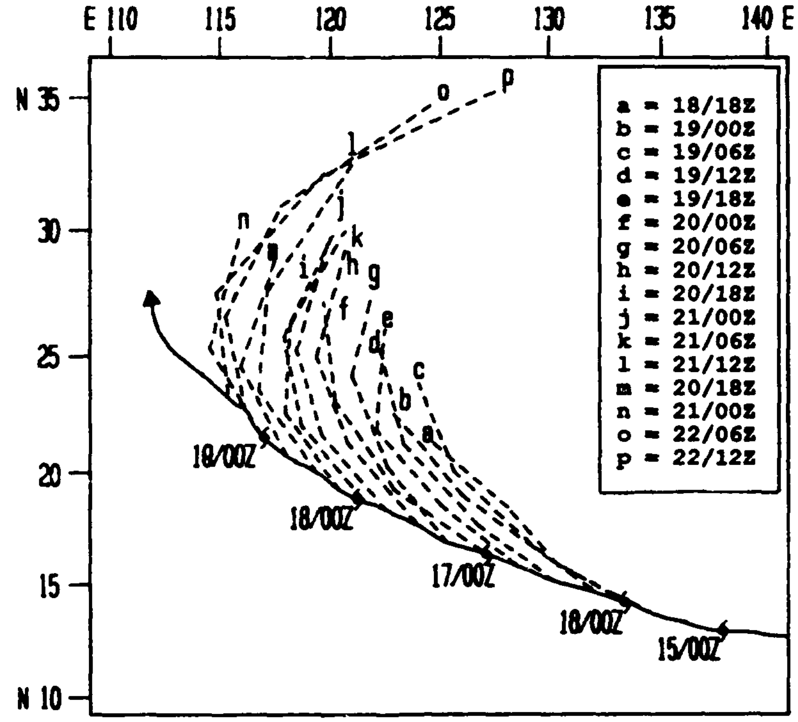


Figure 3-06-2. A comparison of OTCM 72-hour guidance with JTWC's best track. Note OTCM's systematic strong northward bias.

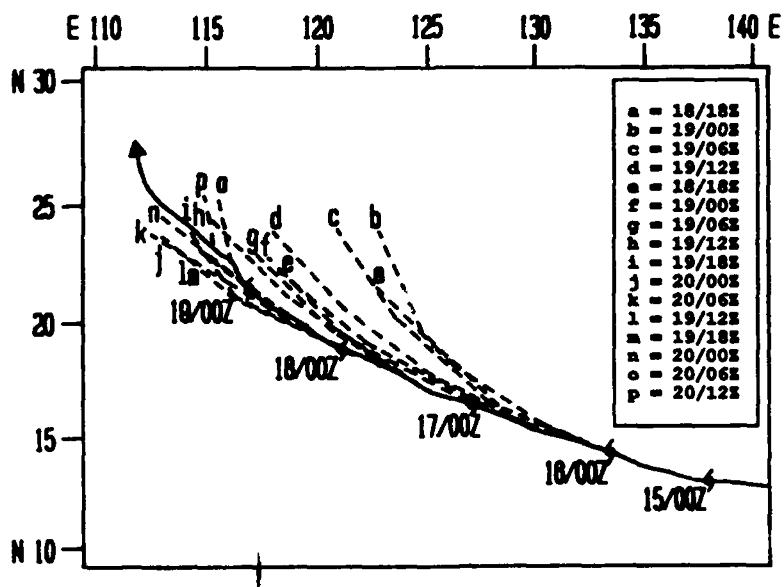


Figure 3-06-3. Seventy-two hour forecasts tended to be north of the best track and more conservative than the OTCM guidance.

subtropical ridge. OTCM is JTWC's operational dynamic aid and in general provides the best performance of all the objective aids. This numerical guidance moved Warren north and east of the island of Taiwan and eventually suggested recurvature within 48- to 72-hours (Figure 3-06-2). However, JTWC's synoptic data analyses and mid-level prognoses maintained the subtropical ridge to the north. This was reinforced by satellite observed persistent minimum cloudiness, which was associated with subsidence and ridging, to the north of Warren. Consequently, recurvature was not forecast (Figure 3-06-3).

From 171800Z to 180000Z, Typhoon Warren weakened as it skirted the northern coast of Luzon with damage to rice and corn crops in northern Luzon estimated to be $10 million.

After its brush with Luzon, the tropical cyclone maintained typhoon intensity until making landfall at 190600Z (Figure 3-06-4) near the city of Shantou in southeastern China. China's official media reported 17 killed and 153 injured by Warren. Additionally, in the province of Guangdong in southeastern China, over 13,000 homes were destroyed and over 150,000 homes damaged. At 200000Z, JTWC issued its final warning on Tropical Storm Warren with the system well inland and northwest of Hong Kong. The remnants of Warren's low-level circulation continued tracking across southern China for another day before merging with a weak summer front, enhancing cloudiness and precipitation.

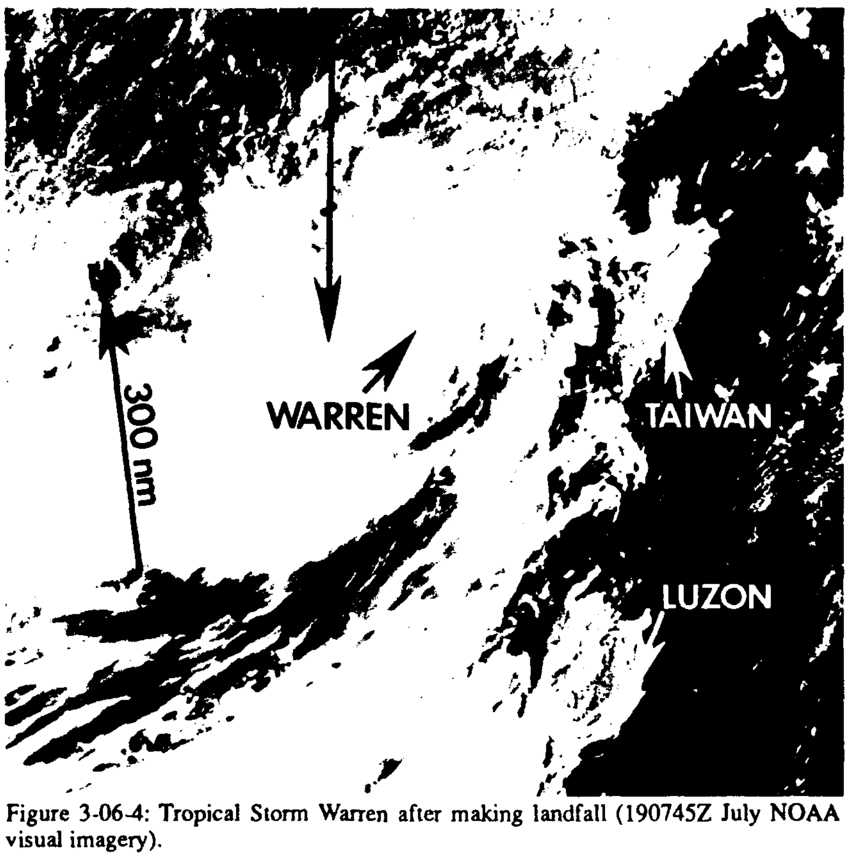
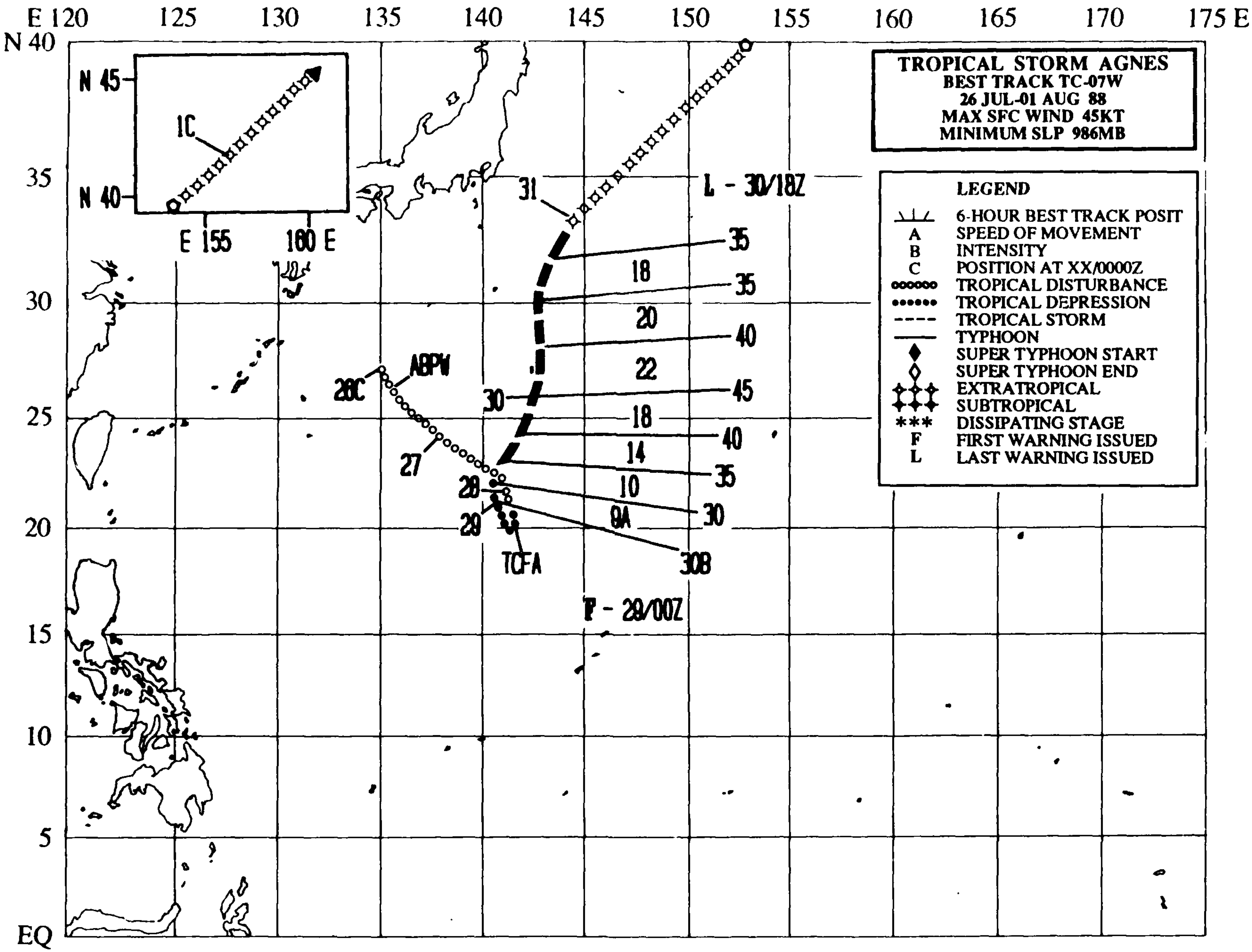


Figure 3-06-4: Tropical Storm Warren after making landfall (190745Z July NOAA visual imagery).



TROPICAL STORM AGNES
BEST TRACK TC-07W
26 JUL-01 AUG 88
MAX SFC WIND 45KT
MINIMUM SLP 986MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 30/18Z
F - 28/00Z
ABPW
28C
27
28
29
TCFA
30B
9A
10
14
18
22
20
31
35
40
45
30
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 40
35
30
25
20
15
10
5
EQ
N 45
N 40
1C
E 155
160 E

TROPICAL STORM AGNES (07W)

Agnes was of note in several respects. It was the second of only two tropical cyclones to develop in July, a month that normally averages five. It played a part in the major shift of the synoptic pattern in the western North Pacific in the latter part of July and later became a small, but vigorous, extratropical cyclone.

As Typhoon Warren (06W) moved into southern China on 19 July, lower tropospheric ridging and fair weather prevailed over eastern China and the Philippine Sea. Once Warren (06W) dissipated, the monsoon trough, instead of maintaining its climatological position across the northern Philippine Islands and southern Philippine Sea, remained over Asia. Southeast of Japan, an area of disturbed weather with lower than normal sea-level pressures and enhanced convection generated in the lower tropospheric troughing (Figure 3-07-1). By 27 July, a closed circulation and supporting southwesterly monsoonal flow at 700 mb had developed along this trough (Figure 3-07-2).

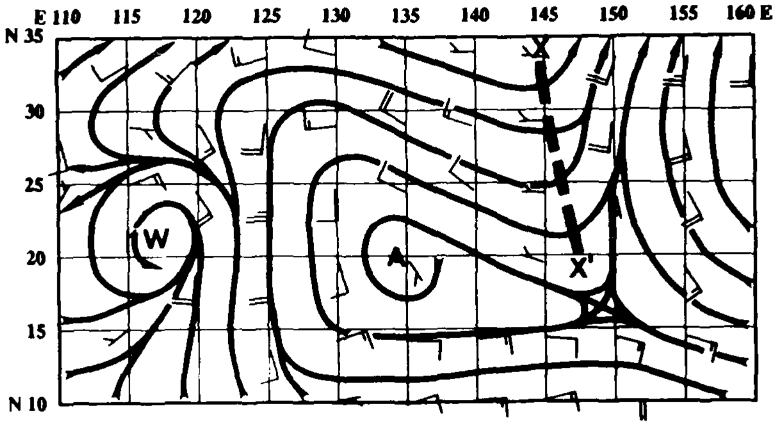


Figure 3-07-1. 700 mb analysis at 190000Z July with Typhoon Warren (06W)(point W) and troughing (line X to X') southeast of Japan.

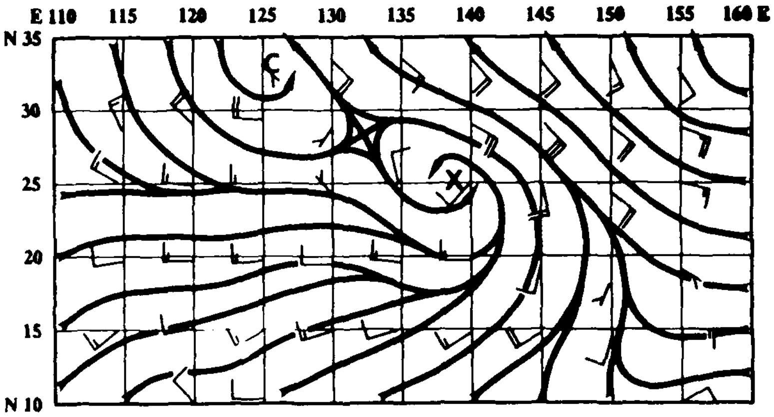


Figure 3-07-2. 270000Z July 700 mb analysis with a closed cyclonic circulation (at point X) and deep west-southwesterly monsoonal flow.

At first, Agnes appeared as a monsoon depression with a low-level cyclonic circulation and deep convection displaced to the south by vertical shear aloft. This was discussed in the Significant Tropical Weather Advisory at 260600Z. The suspect area drifted southeastward in the trough and had a poor potential for development into a significant tropical cyclone due to the unfavorable vertical wind shear of 35 kt (18 m/sec.) When the vertical wind shear dropped to 20 kt (10 m/sec) at 280600Z and satellite imagery indicated increased upper-level outflow and deep convection, the system's potential for significant development was upgraded to "fair". A Tropical Cyclone Formation Alert was issued at 281500Z based on a satellite intensity estimate of 25 kt (13 m/sec). The continued increase in the system's deep convection and overall organization led to the first warning at 290000Z.

Initially, Agnes was forecast to intensify, separate from the monsoon trough and track to the northwest. However, the monsoon trough, which was farther north than normal, merged with a mid-latitude low pressure system to the northeast of Japan. Agnes followed the path of least resistance and accelerated to the north-northeast along this trough axis. The tropical cyclone was upgraded to tropical storm intensity at 291200Z and reached its peak intensity (Figure 3-07-3) of 45 kt (23 m/sec) 12-hours later. The loss of persistent central convection at 301200Z resulted in the issuance of the final warning at 301800Z.

Unfavorable vertical shear from the strong southwesterlies aloft increased and Agnes (Figure 3-07-4) accelerated north-northeastward at more than 30 kt (56 km/hr). Although the system appeared to be

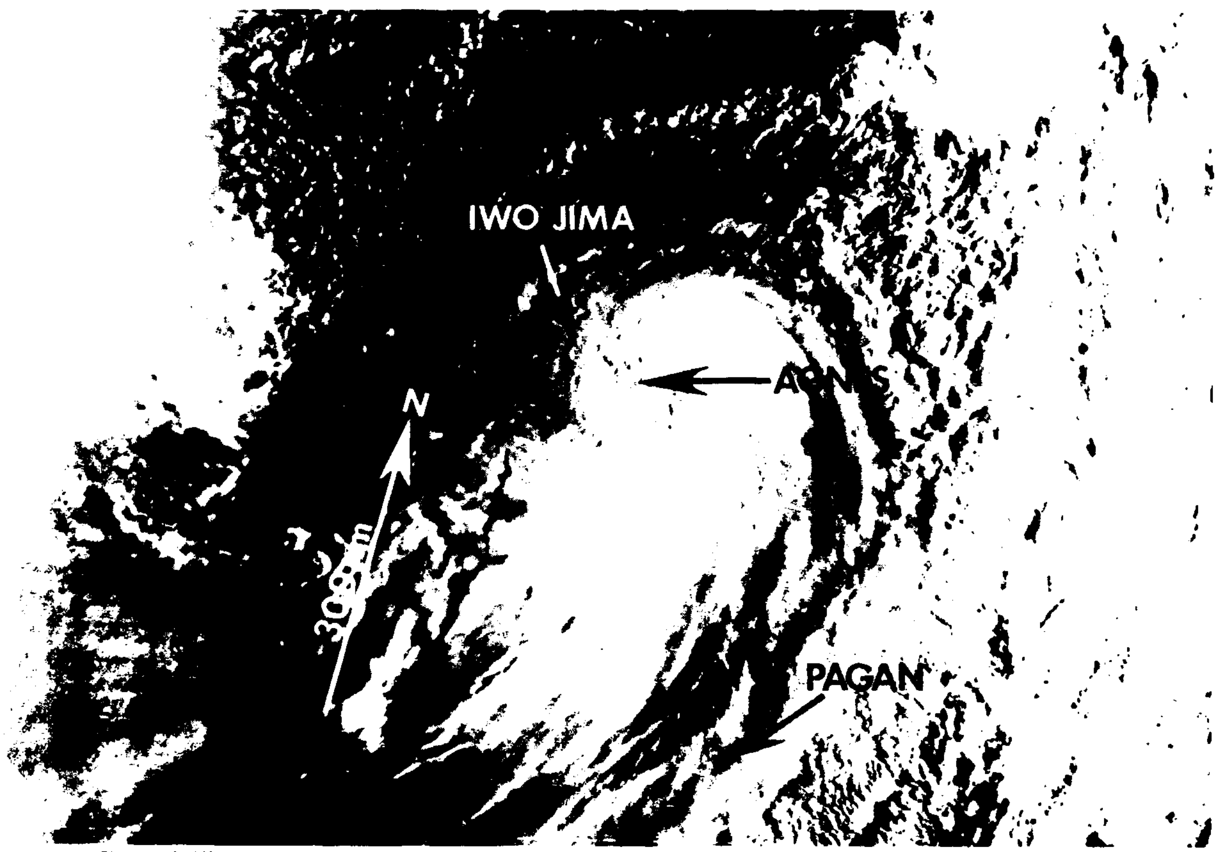


Figure 3-07-3. Agnes, shortly before reaching its peak intensity (292023Z July DMSP visual imagery).

extratropical at 310000Z, ships in the right front quadrant (relative to the forward motion) of this hybrid system reported maximum sustained surface winds of 60 kt (31 m/sec) at 310600Z and 50 kt (26 m/sec) at 311200Z. Herbert and Poteat (1975) address this type of system, or subtropical cyclone, where translational speeds greater than 20 kt (37 km/hr) are added to the intensity estimate determined from the cloud signature. Even though the final warning was issued when the system was at 32 degrees North, Agnes stubbornly maintained some of its tropical characteristics well into the mid-latitudes. No reports of casualties or damages were received.

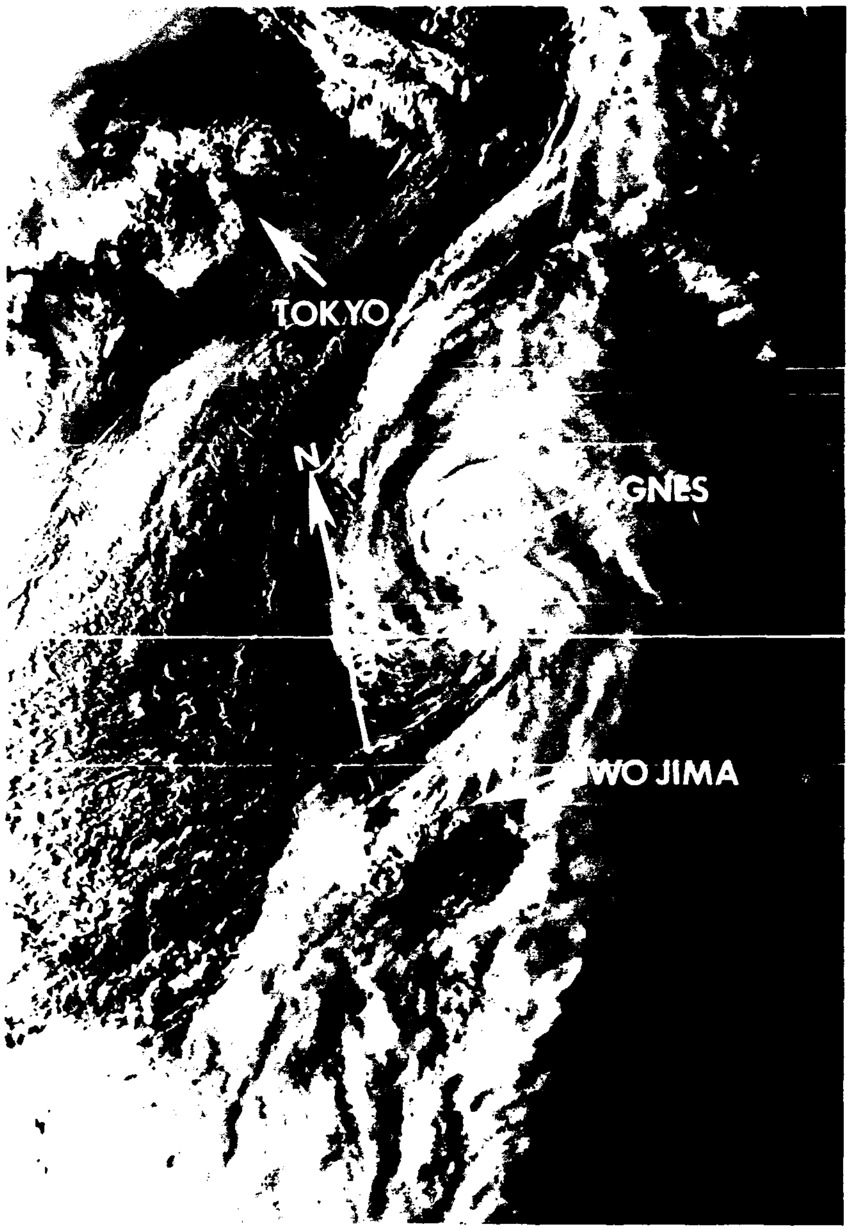
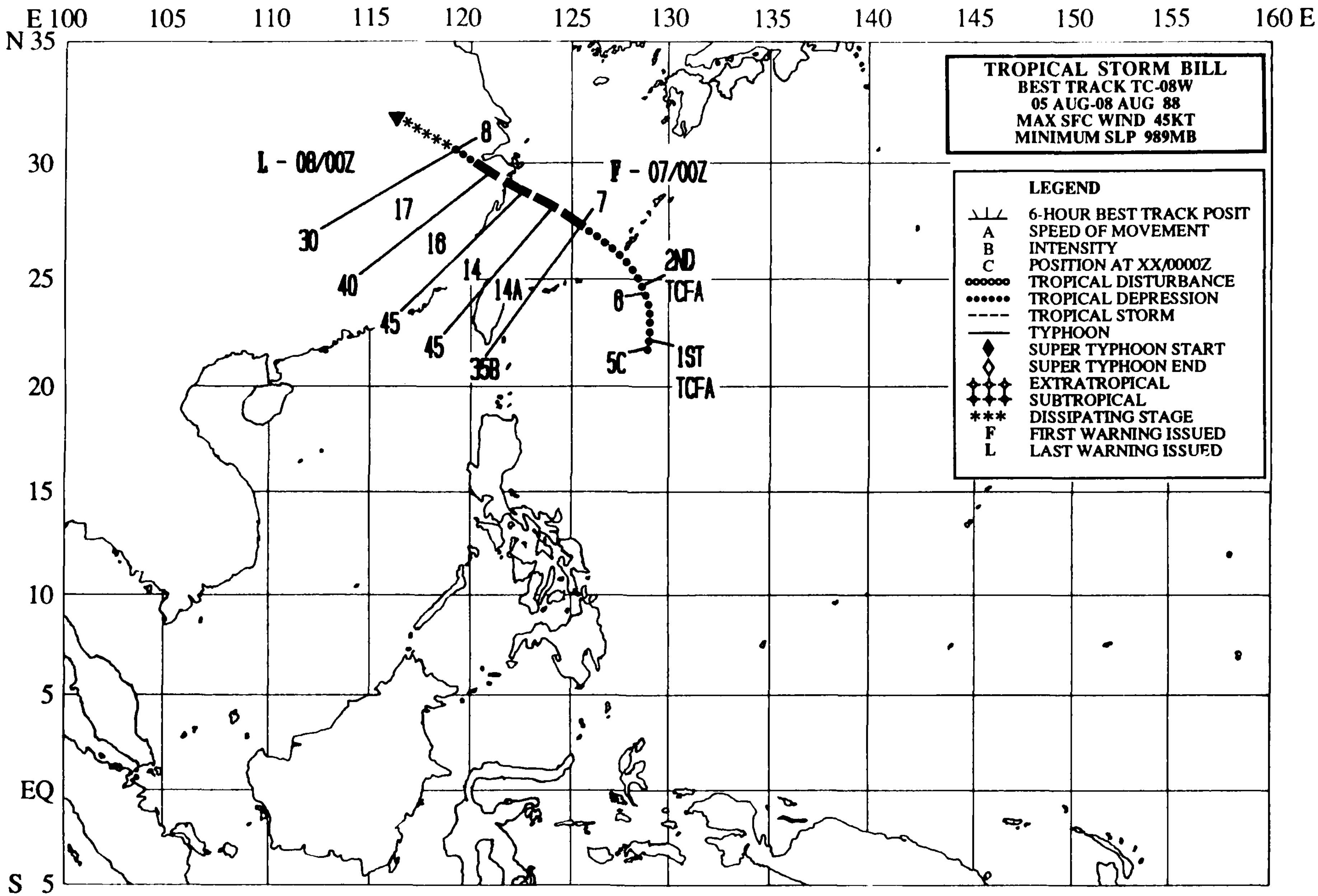


Figure 3-07-4. The remnants of Tropical Storm Agnes during transition into an extratropical system (301829Z July NOAA infrared imagery).


TROPICAL STORM BILL
BEST TRACK TC-08W
05 AUG-08 AUG 88
MAX SFC WIND 45KT
MINIMUM SLP 989MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 08/00Z
F - 07/00Z
8
30
17
40
18
45
14
45
14A
35B
7
2ND
TCFA
6
5C
1ST
TCFA
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ
S 5

TROPICAL STORM BILL (08W)

Tropical Storm Bill was the first of five tropical cyclones to develop during the month of August. It formed in the Philippine Sea, brushed by the island of Okinawa and reached a peak intensity of 45 kt (23 m/sec) before making landfall near Shanghai. Bill remained well organized over China, causing widespread destruction and loss of life. It exemplifies the serious impact that is possible from a system of tropical storm intensity that doesn't dissipate rapidly after moving over land.

On the first day of August the monsoon trough (Figure 3-08-1) stretched from the Gulf of Tonkin across the South China Sea to the Luzon Strait and extended northeastward along the Japanese Islands. By 5 August (Figure 3-08-2) this synoptic feature had undergone a

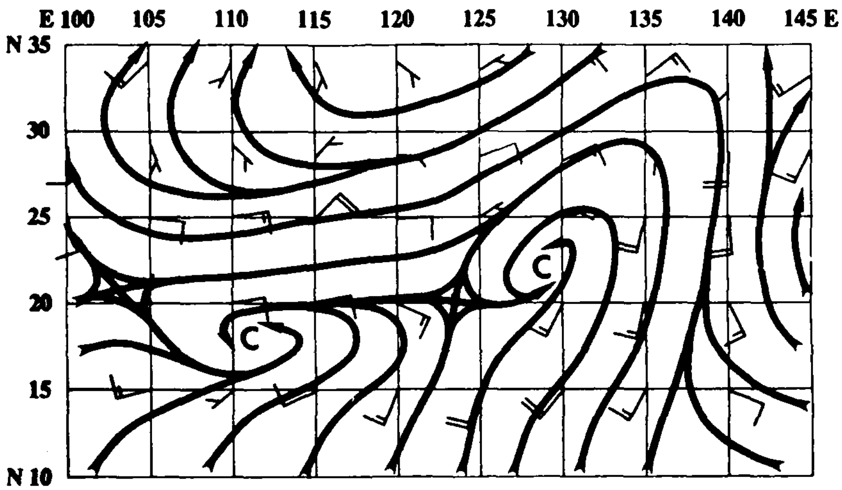


Figure 3-08-1. The 010000Z August 925 mb winds and streamlines show the monsoon trough extending across the South China Sea and northeastward.

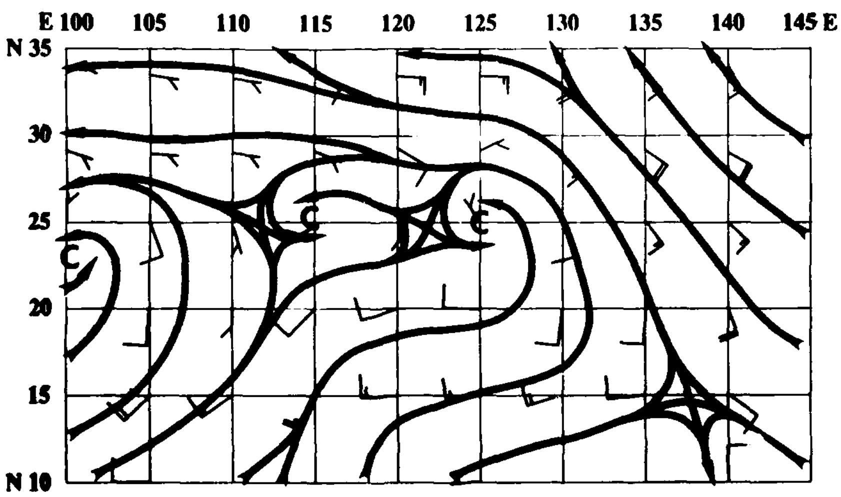


Figure 3-08-2. The 925 mb winds and streamlines for 051200Z, when compared with Figure 3-08-1, reveal the shift of the monsoon trough into China and its abrupt termination near the island of Okinawa, Japan.

major readjustment. Now it was oriented west-to-east over southern China and terminated abruptly near the island of Okinawa, Japan. Excess relative cyclonic vorticity, low-level convergence and associated enhanced convection persisted near the eastern end of the trough. With the environment favorable for tropical cyclogenesis, Bill rapidly consolidated and at 050430Z the first Tropical Cyclone Formation Alert was issued on the system. Early on 6 August the cloudiness associated with the tropical disturbance (Figure 3-08-3) separated from the maximum cloud zone. As the tropical cyclone moved away from the axis of the monsoon trough, it came under the steering influence of the subtropical ridge to the

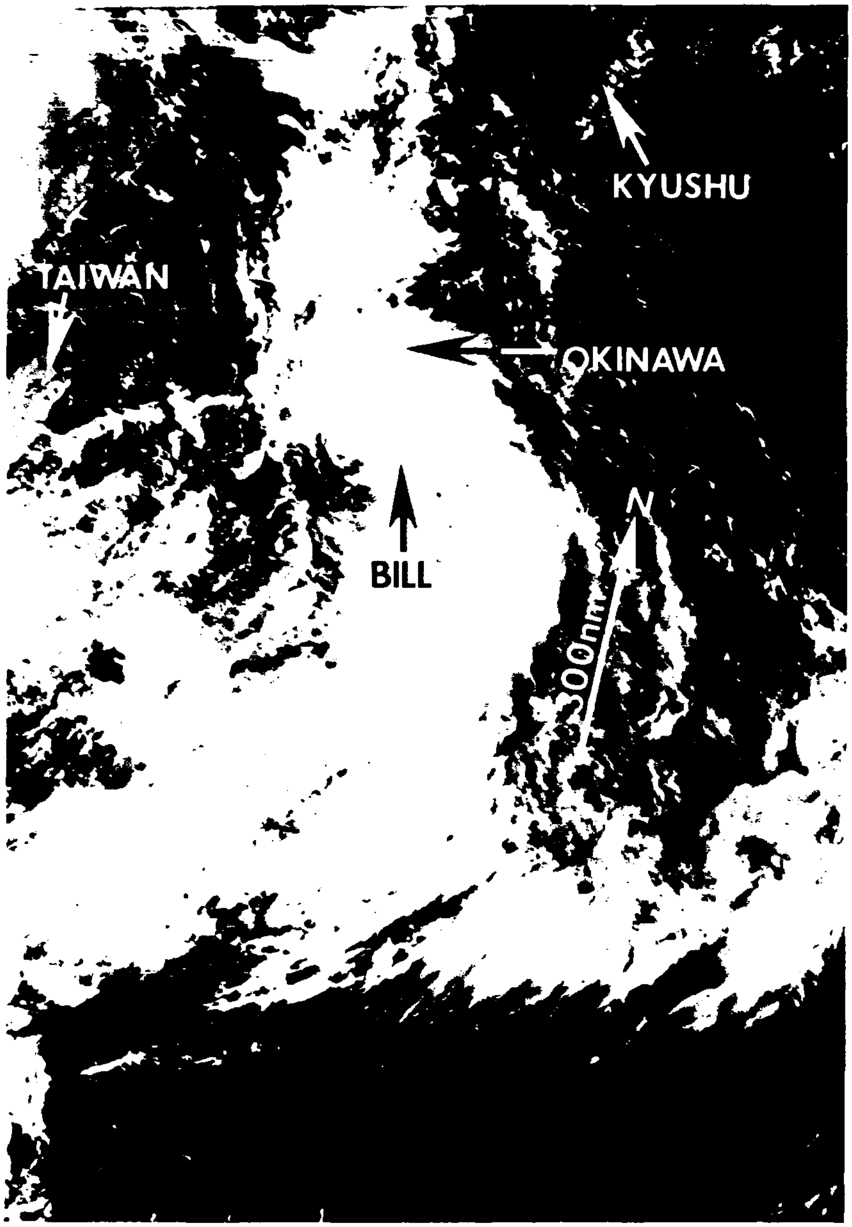


Figure 3-08-3. Bill as a tropical disturbance south of the island of Okinawa (060009Z August DMSP visual imagery).

northeast. The track, which was initially to the north, became northwestward. Consolidation continued, but the pace slowed, and at 060330Z a second Alert was issued. The center of the low-level circulation passed just southwest of the southern tip of Okinawa at 061500Z. Kadena Air Base (WMO 47931) reported a minimum sea-level pressure of 997 mb, sustained surface winds of 20 kt (10 m/sec) and a peak surface gust of 40 kt (21 m/sec). Earlier, Kadena's 061200Z upper-air sounding indicated a layer between the 875 mb and 550 mb levels of 35 to 40 kt (18 to 21 m/sec) winds, which supported the peak gusts.

Slow intensification progressed and the first warning (070000Z) on Tropical Storm Bill followed a satellite intensity estimate of 35 kt (18 m/sec) (Figure 3-08-4). At 070600Z, Bill reached a peak intensity of 45 kt (23 m/sec) and

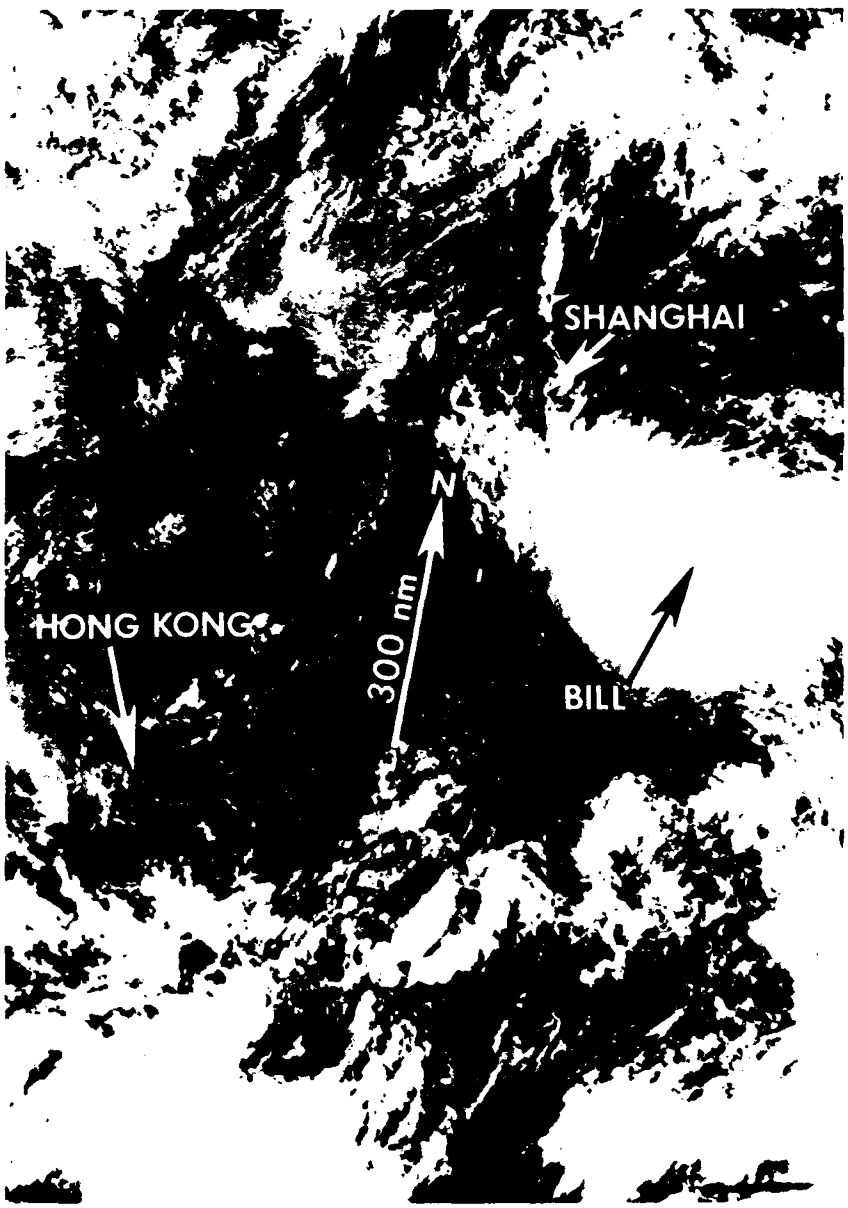


Figure 3-08-4. Bill, shortly after being upgraded to tropical storm intensity (070131Z August DMSP visual imagery).

sustained it until making landfall 120 nm (222 km) south of Shanghai.

Once overland, instead of rapidly dissipating, Bill retained its convection and organization (Figure 3-08-5). At 080000Z, the intensity was downgraded to a tropical depression and the final warning issued. The remains of this cloud system tracked to the northwest and could still be identified on satellite imagery two days later.

Bill's slow dissipation resulted in extensive damage and loss of life in China. Torrential rains led to widespread flooding and local topographic effects may have produced wind gusts as high as 70 kt (35 m/sec). When it was all over, at least 110 people had perished and numerous bridges, dams and watercraft were damaged or destroyed. News releases from China reported "the worst economic loss from a storm in 30 years."

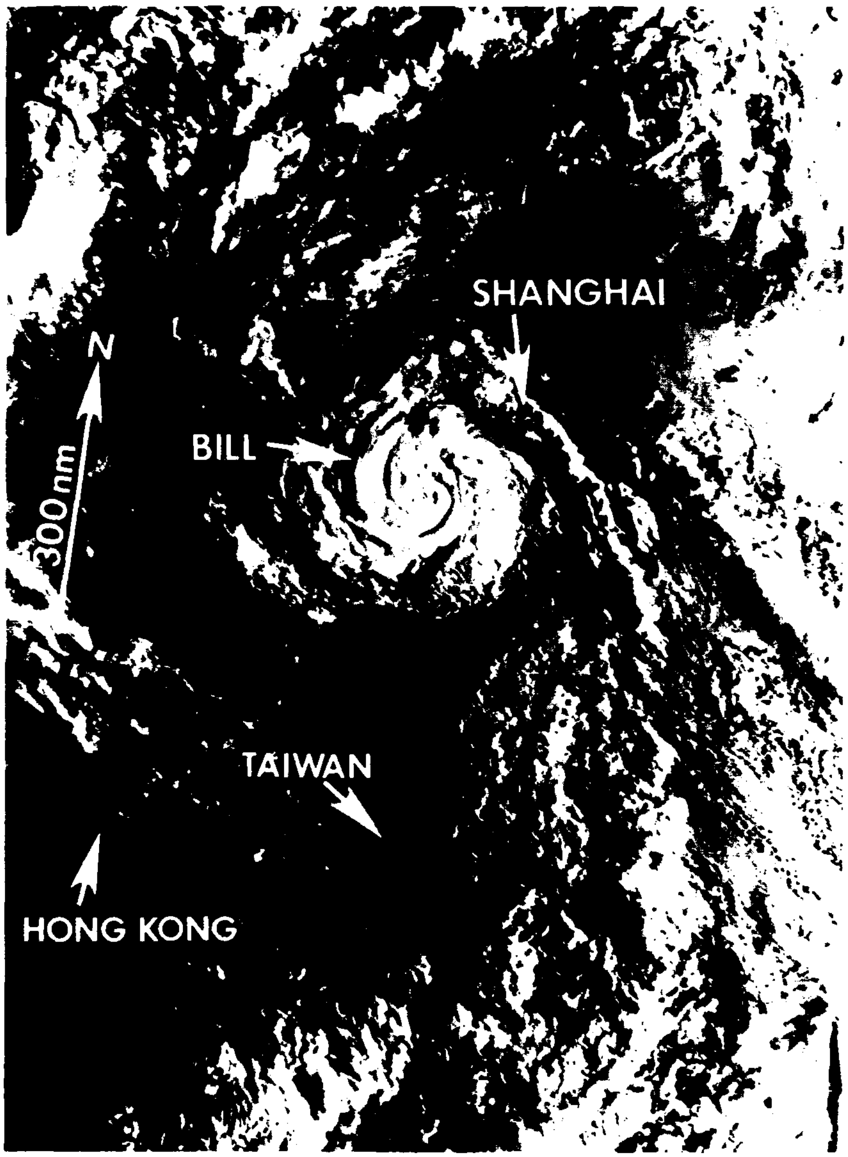
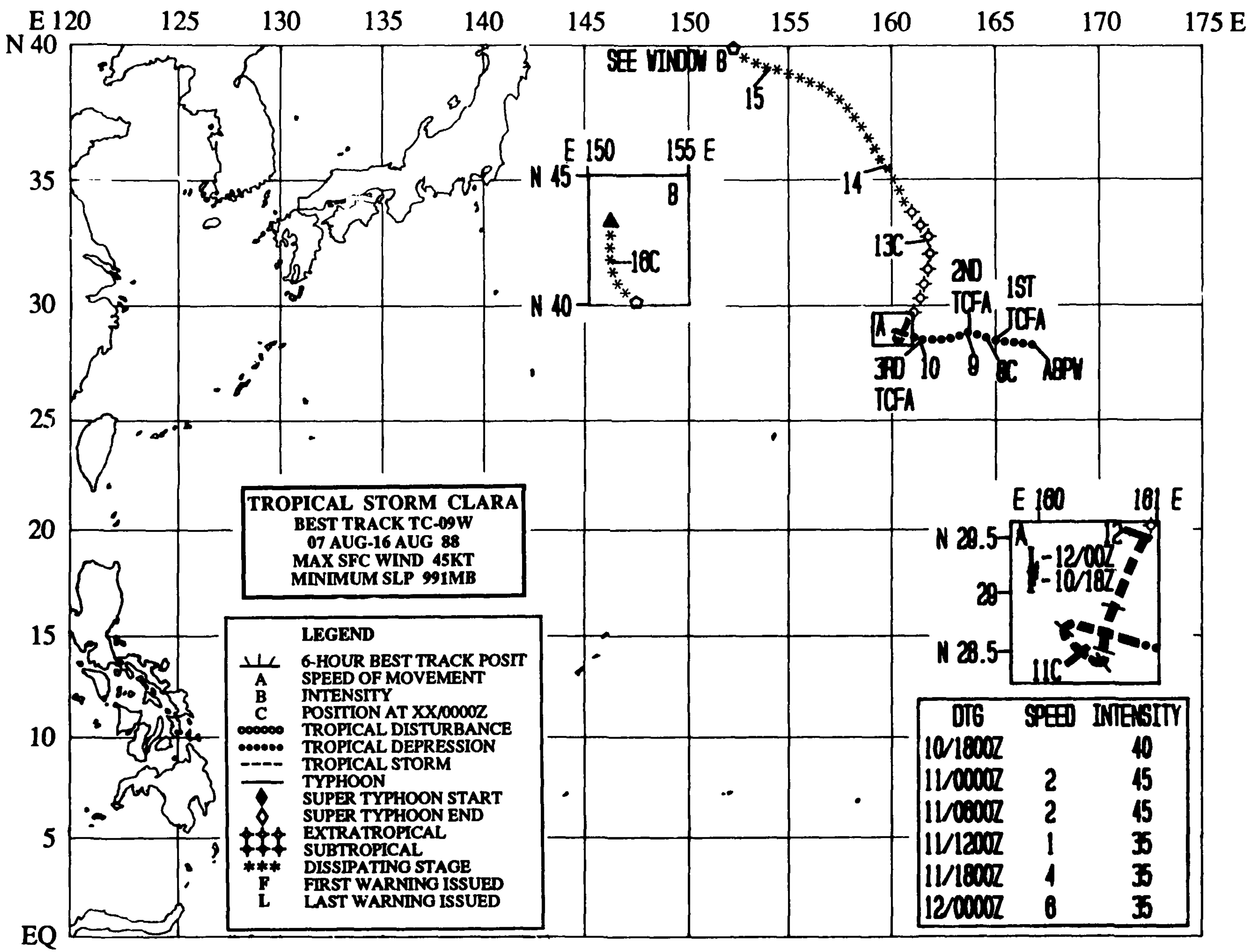


Figure 3-08-5. Tropical Storm Bill continued to be a very well organized system, despite having already been over land for several hours (072156Z August DMSP visual imagery).

Intentionally left blank.


TROPICAL STORM CLARA
BEST TRACK TC-09W
07 AUG-16 AUG 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
SEE WINDOW B
15
14
13C
2ND TCFA
1ST TCFA
3RD TCFA
10
9
8C
ABPW
A
E 150
155 E
N 45
N 40
B
16C
E 160
181 E
N 28.5
29
N 28.5
12
-12/00Z
-10/18Z
11C
DTG SPEED INTENSITY
10/1800Z 40
11/0000Z 2 45
11/0600Z 2 45
11/1200Z 1 35
11/1800Z 4 35
12/0000Z 6 35
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 40
35
30
25
20
15
10
5
EQ

TROPICAL STORM CLARA (09W)

Tropical Storm Clara was the second of five significant tropical cyclones to develop during August. Although hindered by vertical wind shear, Clara proved to be very persistent. Even after the central deep convection was stripped away and the final warning issued, the residual cyclonic vorticity could be identified four days later as a spiral of low-level stratocumulus on the satellite imagery.

Clara was originally detected on satellite imagery as an area of weakly organized convection about 540 nm (1,000 km) north of Wake Island and it was mentioned on the Significant Tropical Weather Advisory on 070600Z August. Easterly flow along the southern edge of the subtropical ridge steered the disturbance westward. Over the next 16-hours the convection persisted and became more organized. The satellite intensity analysis at 072126Z indicated a shearing-type cloud pattern with sustained surface winds of 30 kt (15 m/sec) and an exposed low-level circulation defined by cumulus lines spiraling inwards. The first Tropical Cyclone Formation Alert followed at 072330Z. A second Alert was issued at

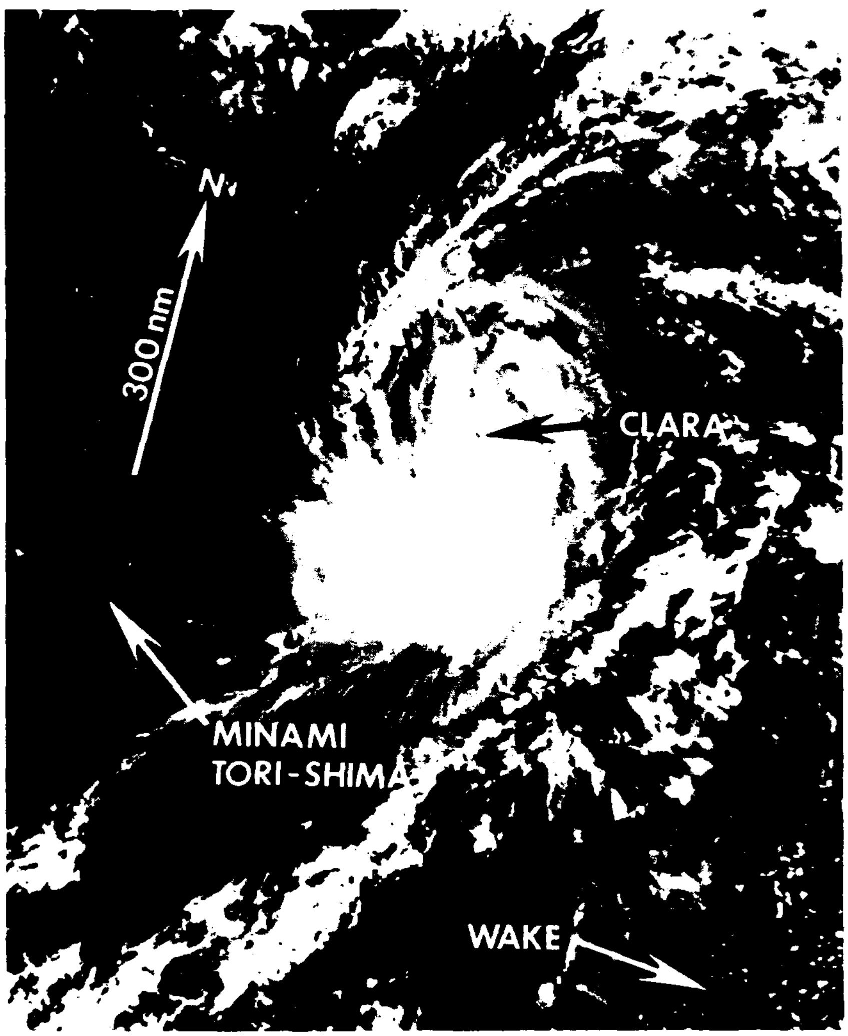


Figure 3-09-1. Tropical Storm Clara, shortly after the first warning (102201Z August NOAA visual imagery).

081600Z for procedural, not meteorological, reasons. However, the disturbance experienced stronger vertical wind shear, and its deep convection was displaced more than 90 nm (167 km) north of the circulation center. Based on this, the second Alert was canceled at 090600Z.

Increased central convection on 10 August and an evaluation of satellite imagery and synoptic data, which indicated 20 to 30 kt (10 to 15 m/sec) sustained surface winds, resulted in a third Alert at 100100Z. As the disturbance continued to move westward, its upper-level outflow improved and its central convection increased. The first warning on Tropical Storm Clara was issued at 101915Z. Sustained surface winds at that time were estimated to be 35 kt (18 m/sec) (Figure 3-09-1). Due to the close proximity to regions of stronger vertical wind shear, Clara was not forecast to intensify beyond the 40 to 45 kt (21 to 23 m/sec) range.

As ridging to the west increased, Clara made a small counterclockwise loop while maintaining its 35 kt (18 m/sec) intensity. Clara reached a peak intensity of 45 kt (23 m/sec) at 110000Z and began moving northeastward (Figure 3-09-2) at 110600Z. Analysis of satellite imagery on 12 August

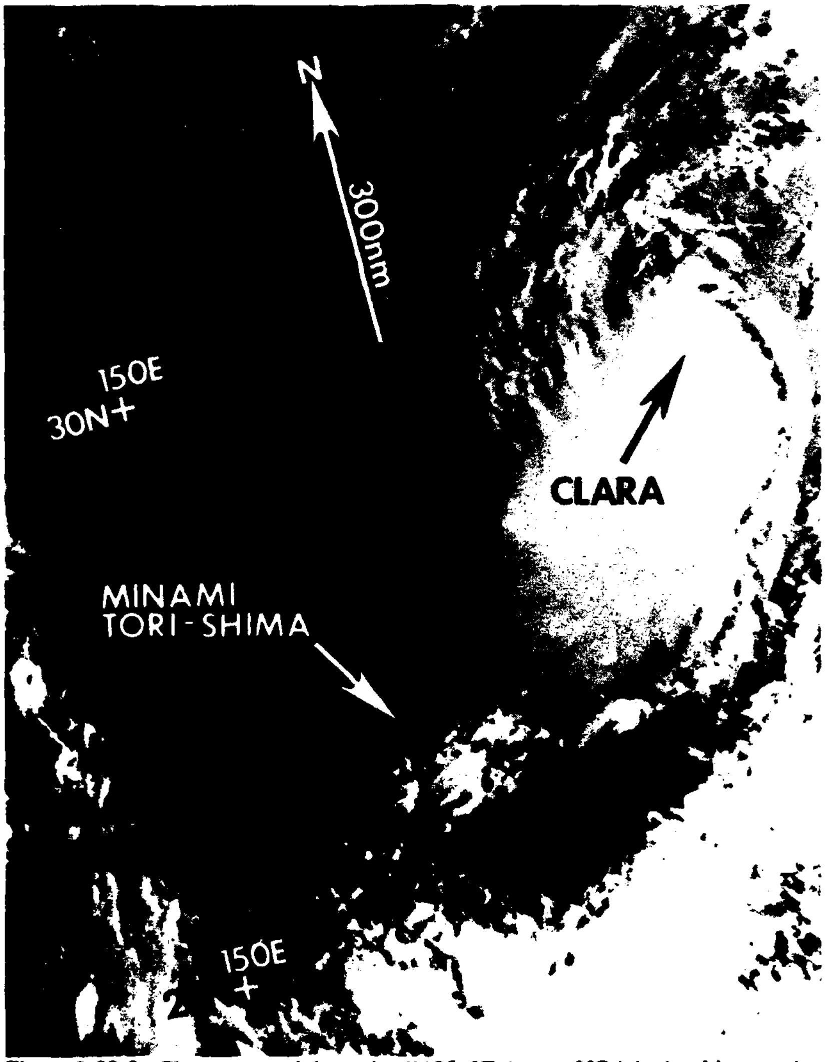
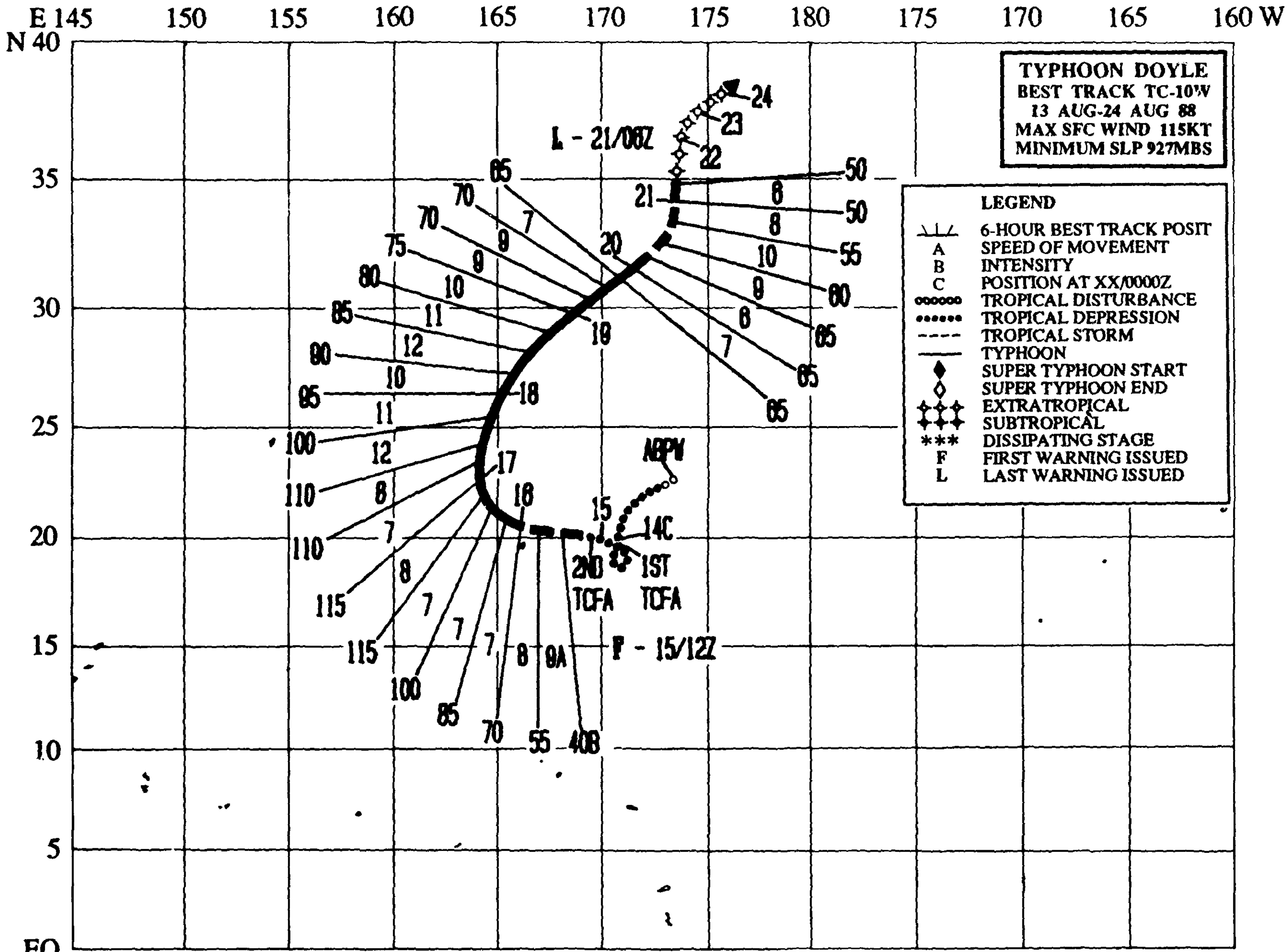


Figure 3-09-2. Clara near peak intensity (110513Z August NOAA visual imagery).

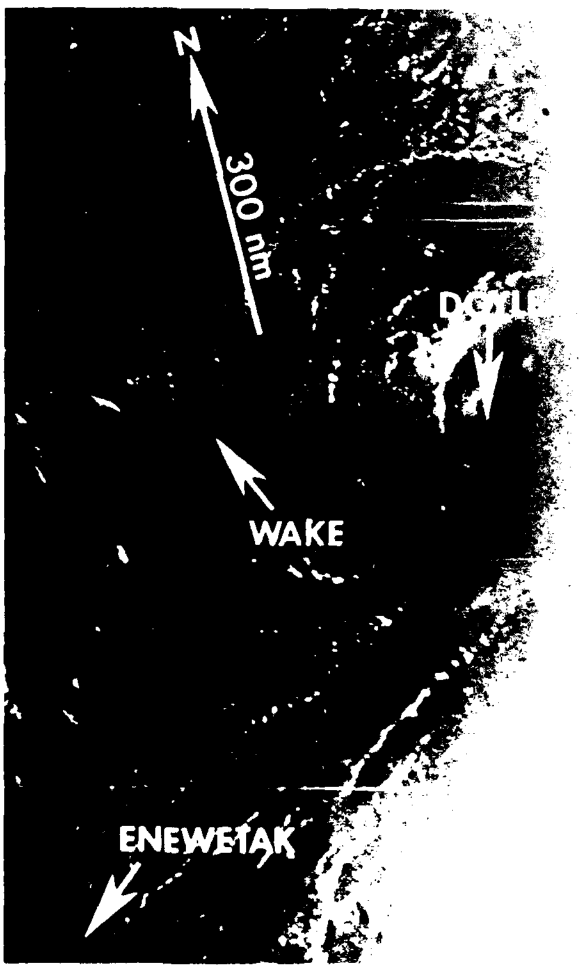
indicated Clara had weakened to 30 kt (15 m/sec) sustained surface winds as its main convection was displaced southeast of the low-level circulation center. The final warning on the system was issued at 120000Z. The remnants of Clara tracked northward, northwestward and, then again, northward for the next four days in response to steering flow around the subtropical ridge to its east. By 16 August, the remains of the system were no longer identifiable. No damage reports relating to Clara were received.


TYPHOON DOYLE
BEST TRACK TC-10W
13 AUG-24 AUG 88
MAX SFC WIND 115KT
MINIMUM SLP 927MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 21/06Z
F - 15/12Z
ABPW
1ST TCFA
2ND TCFA
E 145
150
155
160
165
170
175
180
175
170
165
160 W
N 40
35
30
25
20
15
10
5
EQ

TYPHOON DOYLE (10W)

Typhoon Doyle was the third of five tropical cyclones and the first of two typhoons to occur in the western North Pacific during August. In keeping with the aclimatological trend for the month, Doyle was no exception. It formed north of 20 degrees North latitude, moved south-southwestward and looped before tracking to the northeast.

On 12 August, as Tropical Storm Clara (09W) moved northward and weakened, a portion of the Central Pacific high moved in from the east to fill the void. The high pushed southwestward across the dateline. During the adjustment process, a low-level cloud vortex appeared along the leading edge of the flow and west of the remnants of Hurricane Fabio (08E). The unusual south-southwestward track of this vortex appeared to be related to the steering provided by a lower-tropospheric anticyclone to the north. The Significant Tropical Weather Advisory at 130600Z mentioned the vortex when deep convection became associated with the low-level cyclonic circulation. Throughout the night of the 13th and early morning hours of the 14th, the convection became centralized. This prompted a Tropical Cyclone Formation Alert at 140130Z. Visual and infrared imagery (Figure 3-10-1) at 140743Z implied a well developed low-level inflow. About this time



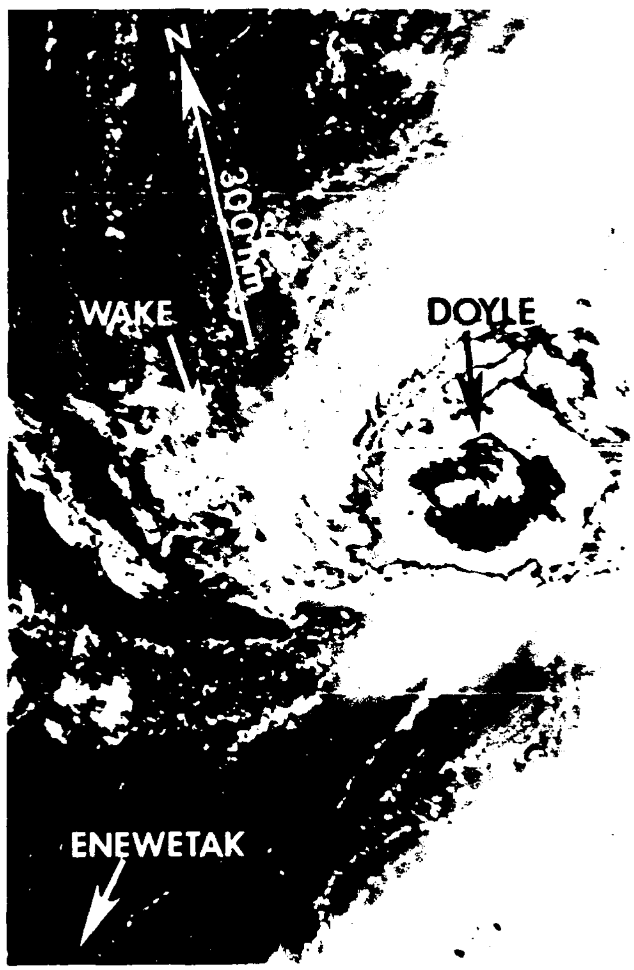


Figure 3-10-1. Satellite imagery of the suspect area (Doyle). Low-level circulation is implied by the lines of cumulus surrounding the center. The left picture is visual and the right is enhanced infrared (140743Z August DMSP visual and infrared imagery).

the system (Doyle) executed a small counterclockwise loop and began tracking west-northwestward. The potential for the system to develop remained good and a second Tropical Cyclone Formation Alert was issued at 150130Z.

The satellite intensity estimate of 40 kt (21 m/sec) maximum surface winds was followed at 151200Z by the first warning, when the system was 96 nm (178 km) east-northeast of Wake Island. For the 24-hour period from 151800Z to 161800Z (Figure 3-10-2) the intensity increased from 50 to 115 kt (26 to 59 m/sec). This was the equivalent of a sixty millibar pressure fall and met the criteria (Dunnavan, 1981) for explosive deepening. Although Doyle, which was close to becoming a compact typhoon, passed 55 nm (102 km) north of Wake Island (WMO 91245) at 152100Z, the island only experienced gusts to 40 kt (21 m/sec). As a result, the low-lying island incurred only minor damage.

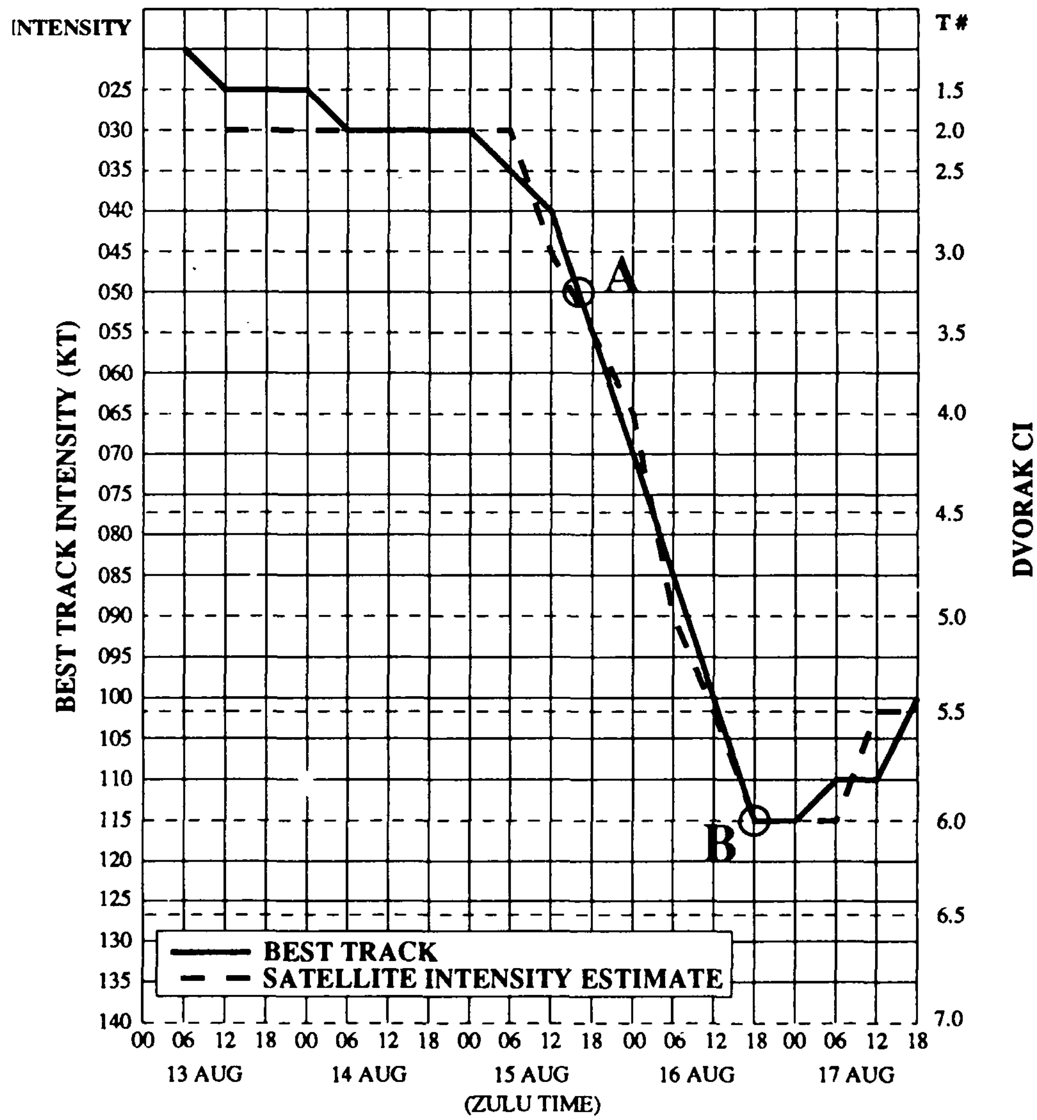


Figure 3-10-2. Time/intensity comparison of satellite intensity estimates for the Guam satellite site and the best track. Notice the extended period of explosive deepening of 30 mb/12-hours from 151800Z (point A) to 161800Z (point B).

Nearing the western periphery of the mid-level subtropical ridge, Doyle peaked in intensity at 161800Z (Figure 3-10-3) and assumed a northward track at 170000Z. To complicate the track forecasts, a TUTT cell stalled, then appeared to dissipate to the north. The main effect of the TUTT cell was to shield the tropical cyclone from strong mid- and upper-level westerlies. As a result, expected acceleration along the track didn't take place and Doyle's speed was never greater than 12 kt (22 km/hr). Doyle's track followed lower pressures and heights present between the subtropical ridge to the southeast and another high cell to the northwest centered near 42° North latitude.

After gradual weakening, Doyle was forecast to become extratropical as the convection began to move into the northeast semicircle at 180900Z. However, some central convection remained until 22 August. Doyle

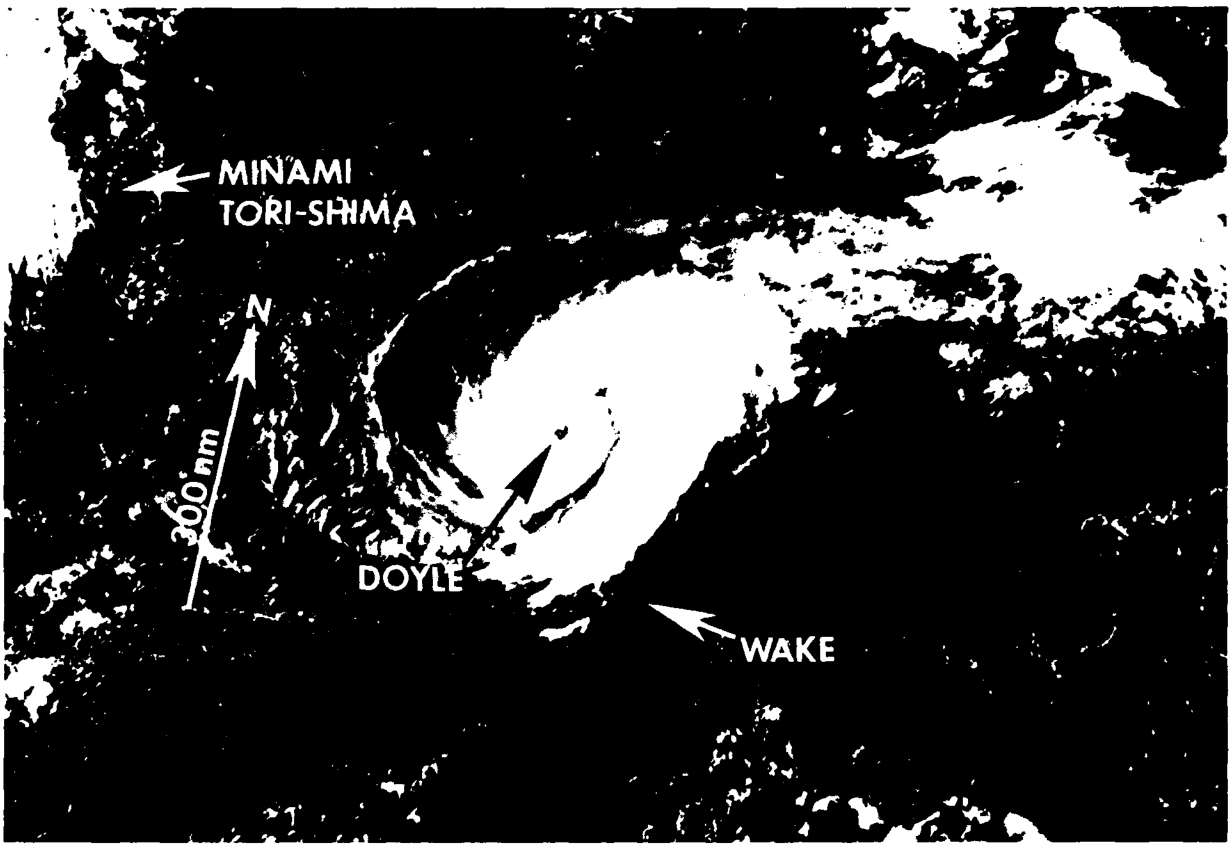


Figure 3-10-3. Satellite imagery of Typhoon Doyle at maximum intensity. The medium sized eye ranged from 20 to 30 nm (37 to 57 km) in diameter (162212Z August DMSP visual imagery).

dissipated over colder water as the system slowed and moved northeastward.

Doyle fell into the "other" track category for several reasons: rapid south-southwestward movement for 24-hours, looping and interaction with a TUTT cell while at typhoon intensity. Normally, tropical cyclone objective forecast guidance does not perform well for aclimatic systems. Figure 3-10-4 compares the final best track and the performance of the two best performing aids, CSUM and OTCM, up to the major track change at 170000Z. Although OTCM had the lowest mean forecast errors at 72-hours of all the aids, it was slow in catching the major track change to the northeast. CSUM had the same problem predicting this track change.

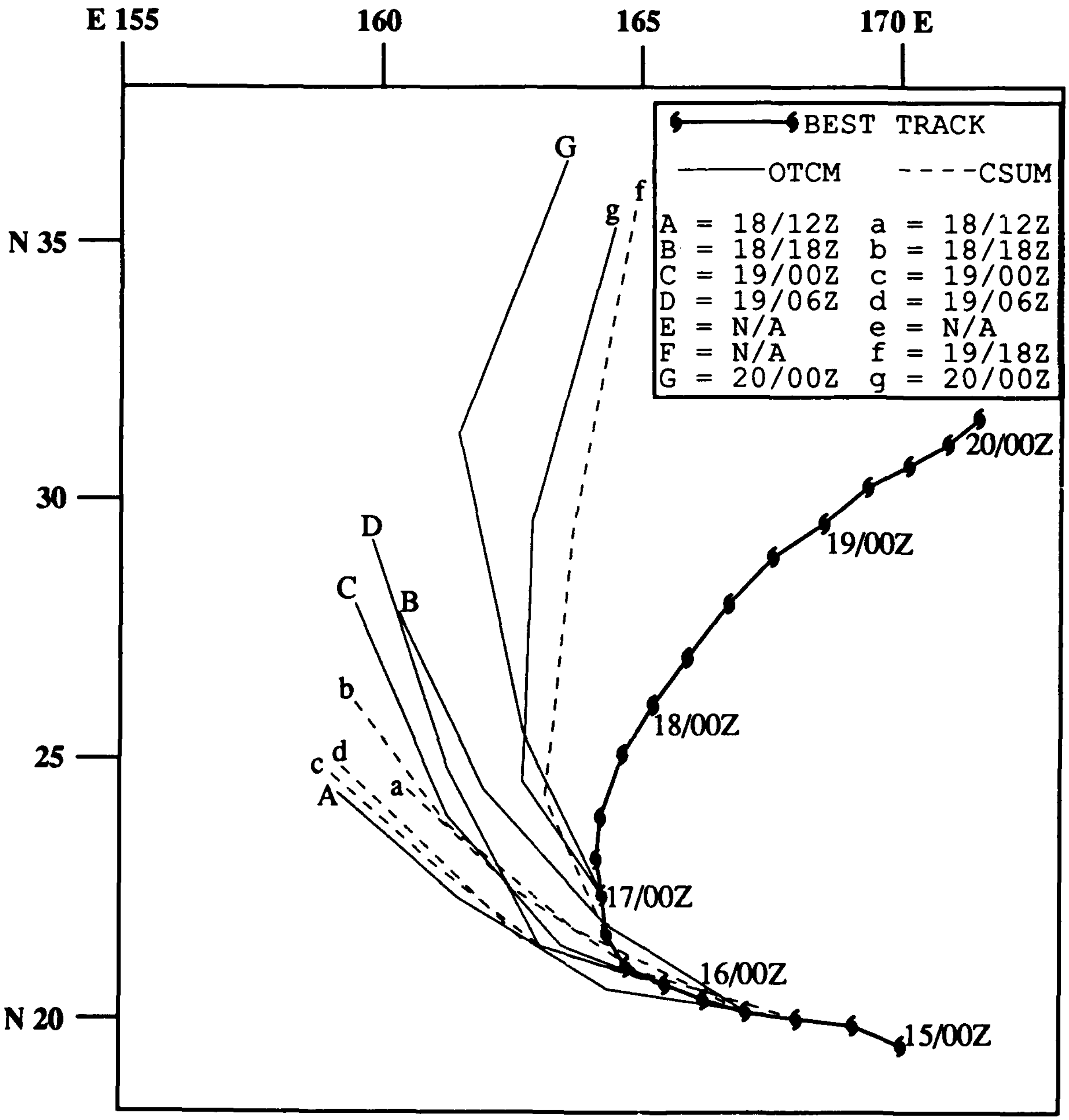
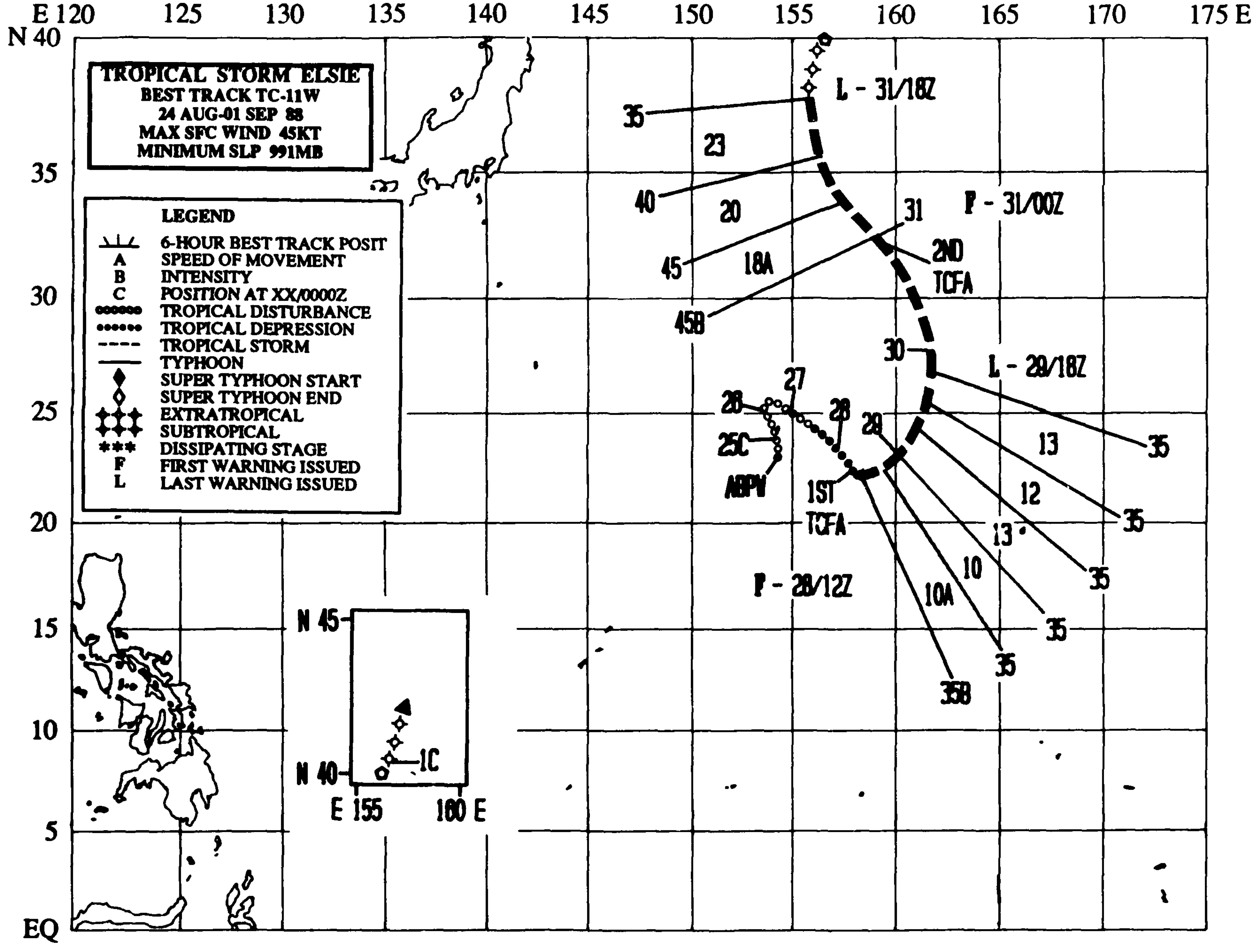
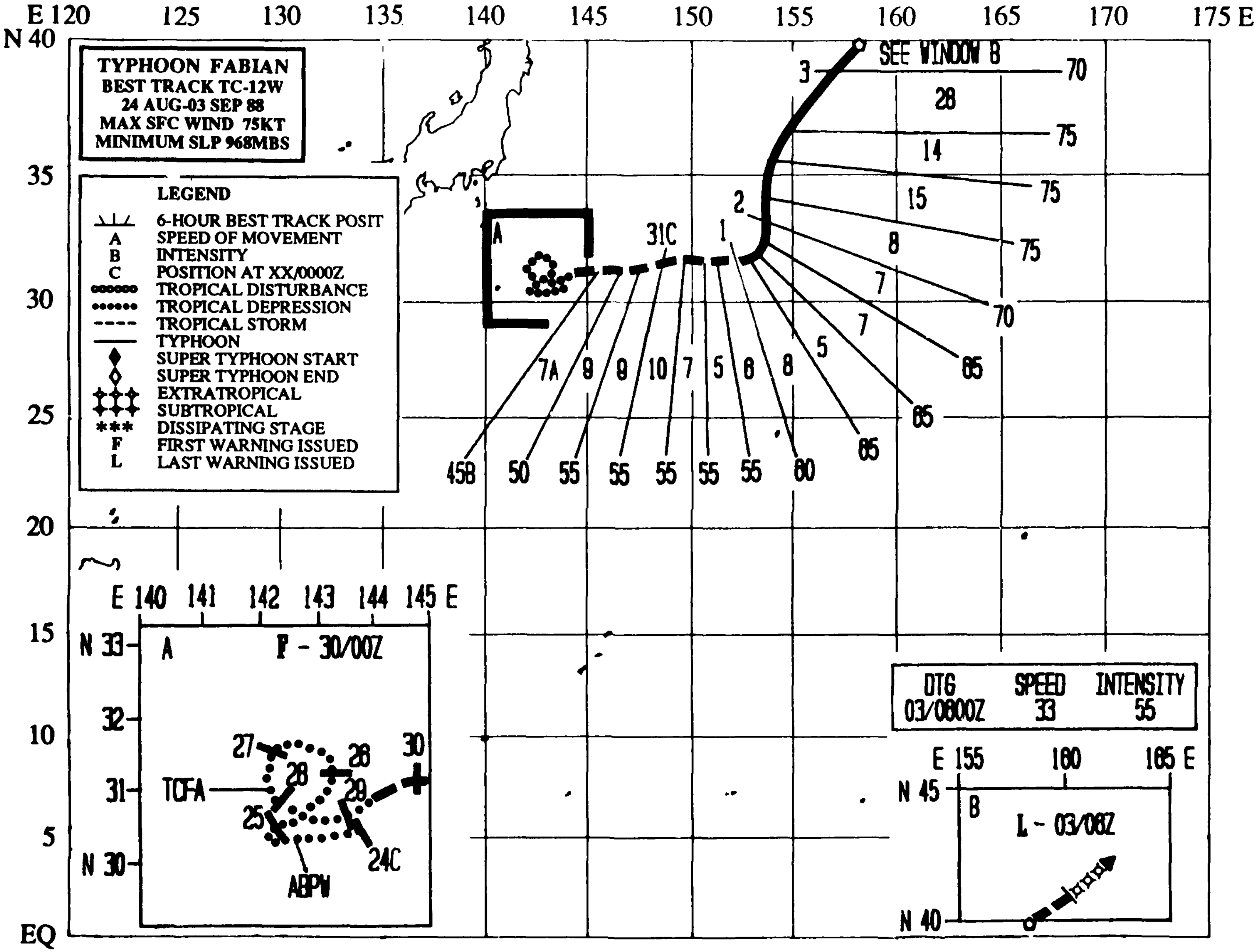


Figure 3-10-4. Graphical display of selected objective aids performance (OTCM and CSUM).


TROPICAL STORM ELSIE
BEST TRACK TC-11W
24 AUG-01 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 31/18Z
F - 31/00Z
L - 29/18Z
F - 28/12Z
2ND TCFA
1ST TCFA
ABPW
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 40
35
30
25
20
15
10
5
EQ
N 45
N 40
E 155
160 E
1C



TYPHOON FABIAN
BEST TRACK TC-12W
24 AUG-03 SEP 88
MAX SFC WIND 75KT
MINIMUM SLP 968MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
SEE WINDOW B
DTG 03/0800Z
SPEED 33
INTENSITY 55
F - 30/00Z
L - 03/08Z
TCFA
ABPW
24C
31C

TROPICAL STORM ELSIE (11W) AND TYPHOON FABIAN (12W)

Elsie and Fabian were the last of five significant tropical cyclones to develop in August. They both initially displayed erratic movement as immature systems within the larger monsoon trough, interacted as a binary pair (Brand, 1968) and, later, became extratropical.

Both systems were first detected on 24 August and mentioned on the Significant Tropical Weather Advisory as areas of persistent convection in the monsoon trough, that was anomalously far north and extended southeastward from Japan. Typical of formative vortices in the larger monsoon trough, their tracks were less than straight forward. Fabian's track wobbled around until 28 August, when it sped off towards the east on a possible collision course with Elsie. In the interim, Fabian required three Tropical Cyclone Formation Alerts: the first at 271430Z based on a 30 kt (15 m/sec) satellite estimate of surface winds, a second at 281430Z and the third at 291230Z when the tropical disturbance retained its potential for development and failed to weaken. Finally, Fabian's convection consolidated (Figure 3-11/12-1), resulting in a satellite intensity estimate of 45 kt (23 m/sec) and the first warning at 300000Z.

In the meantime, Elsie, which was located at the southeastern end of the monsoon trough, was in an area of stronger low-level convergence and associated cloudiness, but

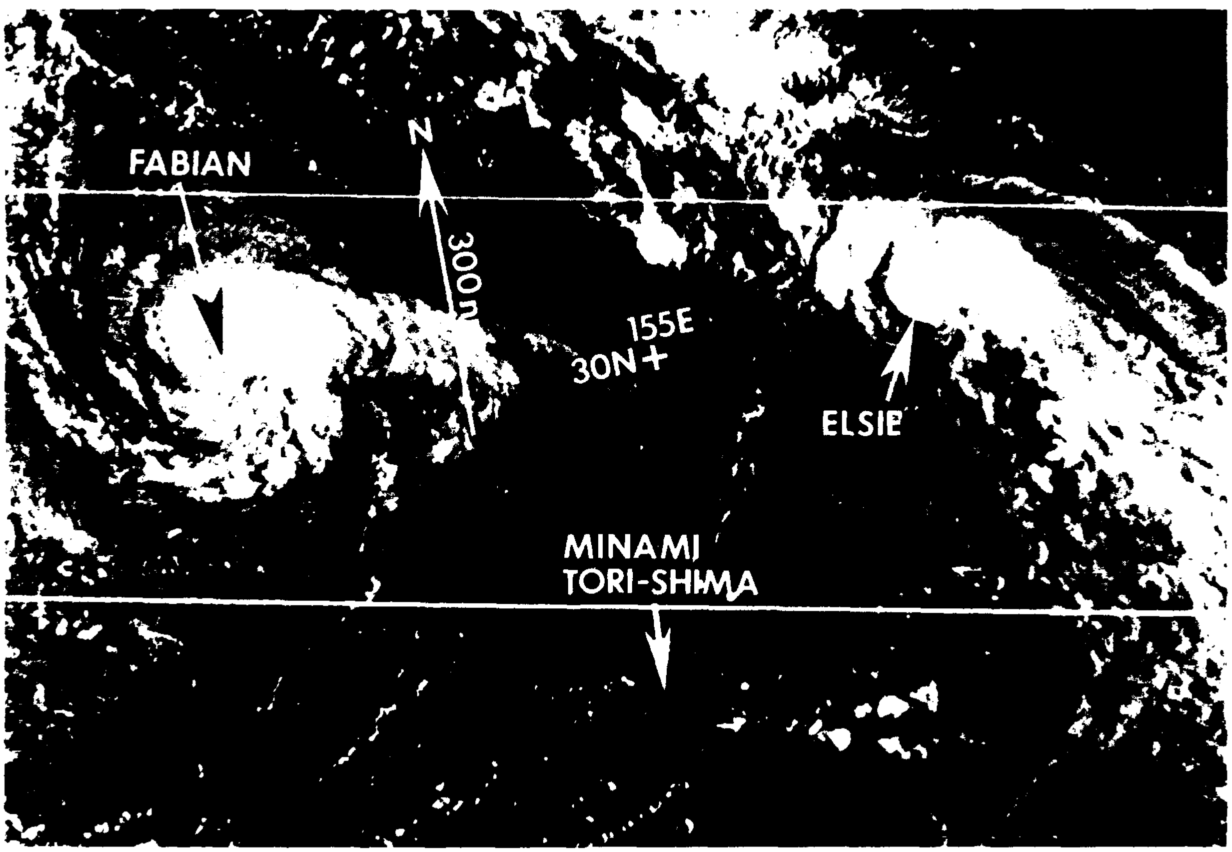


Figure 3-11/12-1. Fabian at tropical storm intensity is on the left. Tropical Storm Elsie is on the right (301140Z August DMSP visual imagery).

suffered from lack of central convection. Better organization at 280600Z with estimated surface winds of 30 kt (15 m/sec) from the satellite analysis led to a Tropical Cyclone Formation Alert at 280900Z. The first warning followed at 281200Z based on satellite intensity estimates of 35 kt (18 m/sec). At this point Elsie's course, which had been southeastward, abruptly changed to northeastward. As a consequence, the monsoon trough also began to shift northward. This reorientation of the trough axis is the most probable explanation for Fabian's unusual track to the east.

At 281200Z, Elsie and Fabian were separated by 1070 nm (1982 km). The two systems closed on each other until only a 400 nm (741 km) separation remained three days later. Figure 3-11/12-2 shows the two best tracks with the locus of midpoints (point A to point B) between each system at six hourly intervals. Plotting the locus of midpoints at one point (C) in Figure 3-11/12-3 and replotting the relative locations of Elsie and Fabian, the cyclonic motion of the binaries (Dong and Neumann, 1983) is captured.

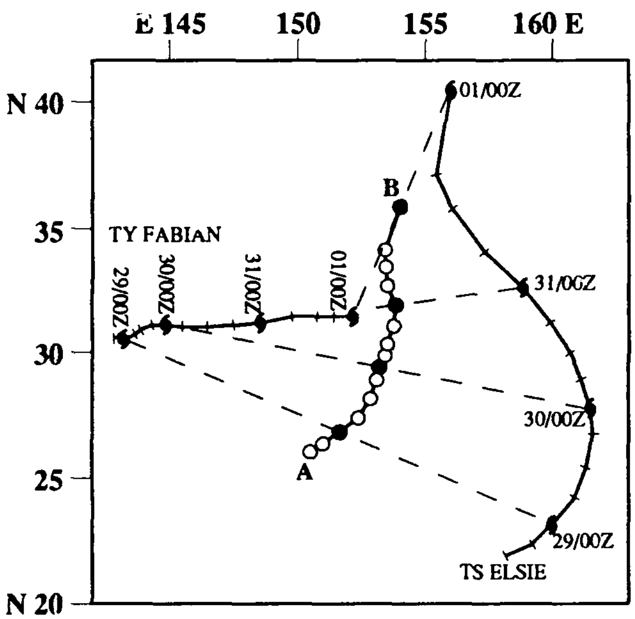


Figure 3-11/12-2. Tracks for Elsie and Fabian for the period 281200Z August to 010000Z September. For each respective six hourly position for the two systems a midpoint is plotted. The locus of these midpoints stretches from point A to point B.

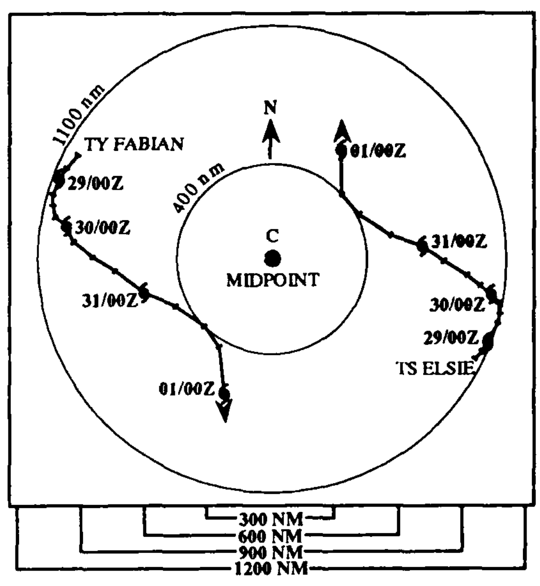


Figure 3-11/12-3. For the period 281200Z August to 010000Z September the plotted positions of Elsie and Fabian relative to the midpoint (reference Figure 3-11/12-2) at point C describe the motion of this binary system.

While this interaction was taking place, Elsie's convection weakened and the forecast intensity estimate dropped below 35 kt (18 m/sec). This prompted an am ndment of the 291800Z warning, which had called for dissipation in 48-hours over water with remarks that "signs for regeneration would be monitored." It appears that Elsie stabilized as a weak tropical storm and assumed a track to the northwest. The remnants of Elsie were not expected to flare up again due to the binary interaction with Fabian, which reduced the separation between the two and increased the vertical wind shear across Elsie from Fabian's outflow. However, the central convection returned (Figure 3-11/12-4) and a Tropical Cyclone Formation Alert - the second for Elsie - was issued at 302300Z. Elsie's compact reorganization resisted the unfavorable conditions aloft and the Alert was almost immediately upgraded to a regenerated tropical storm at 310000Z.

Once Elsie was past the closest point of approach to Fabian, it changed course to the northeast, accelerated and rapidly became extratropical. The final warning - the second for Elsie - was issued at 311800Z. In contrast,

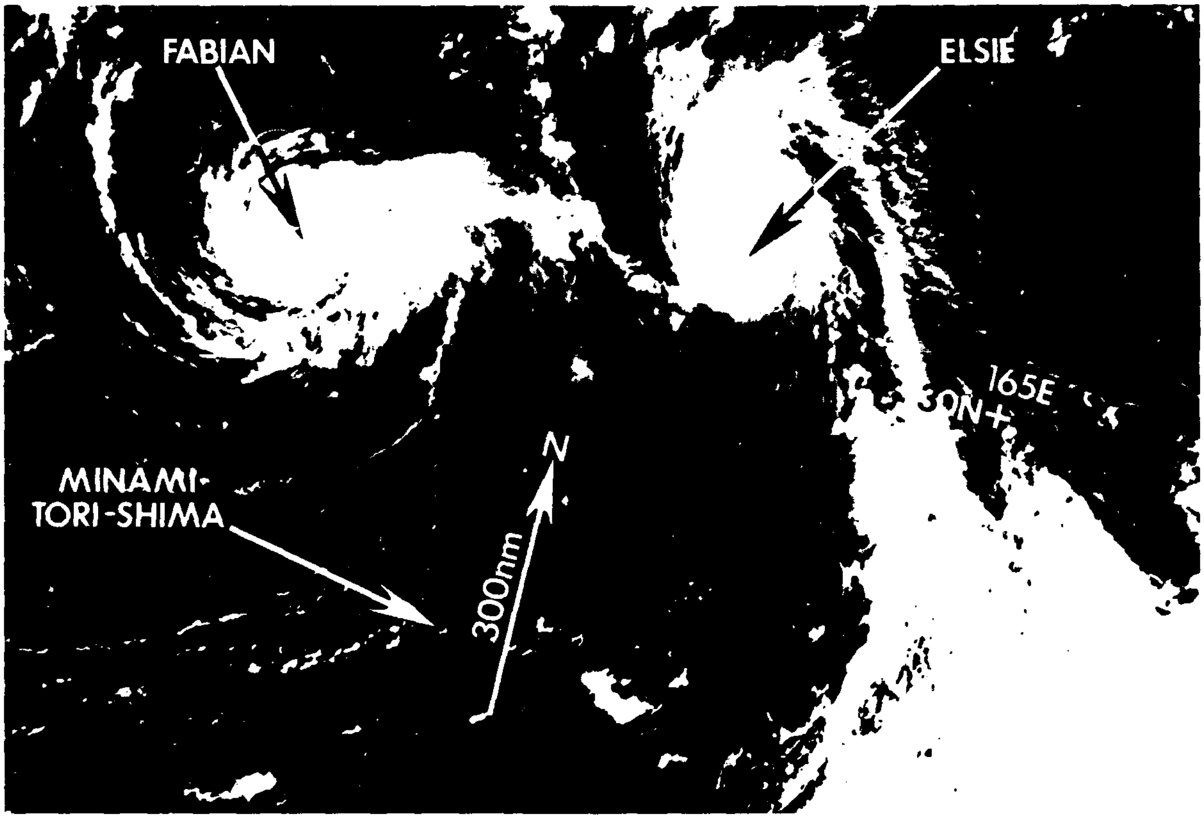


Figure 3-11/12-4. The remnants of Elsie, on the right, undergo a rapid reorganization. The second Tropical Cyclone Formation Alert was issued upon receipt of this picture. Fabian is to the left of Elsie (302240Z August DMSP visual imagery).

Fabian intensified during this encounter and reached typhoon intensity (Figure 3-11/12-5) at 010600Z just prior to making an abrupt track change to the north six hours later. Typhoon Fabian reached a peak intensity of 75 kt (39 m/sec) at 020600Z. By 030000Z, the onset of rapid acceleration and stronger upper-level westerlies led to a loss of convective organization. Fabian was downgraded to tropical storm intensity and finalled at 030600Z. No reports of damage or loss of life were received for these two tropical cyclones.

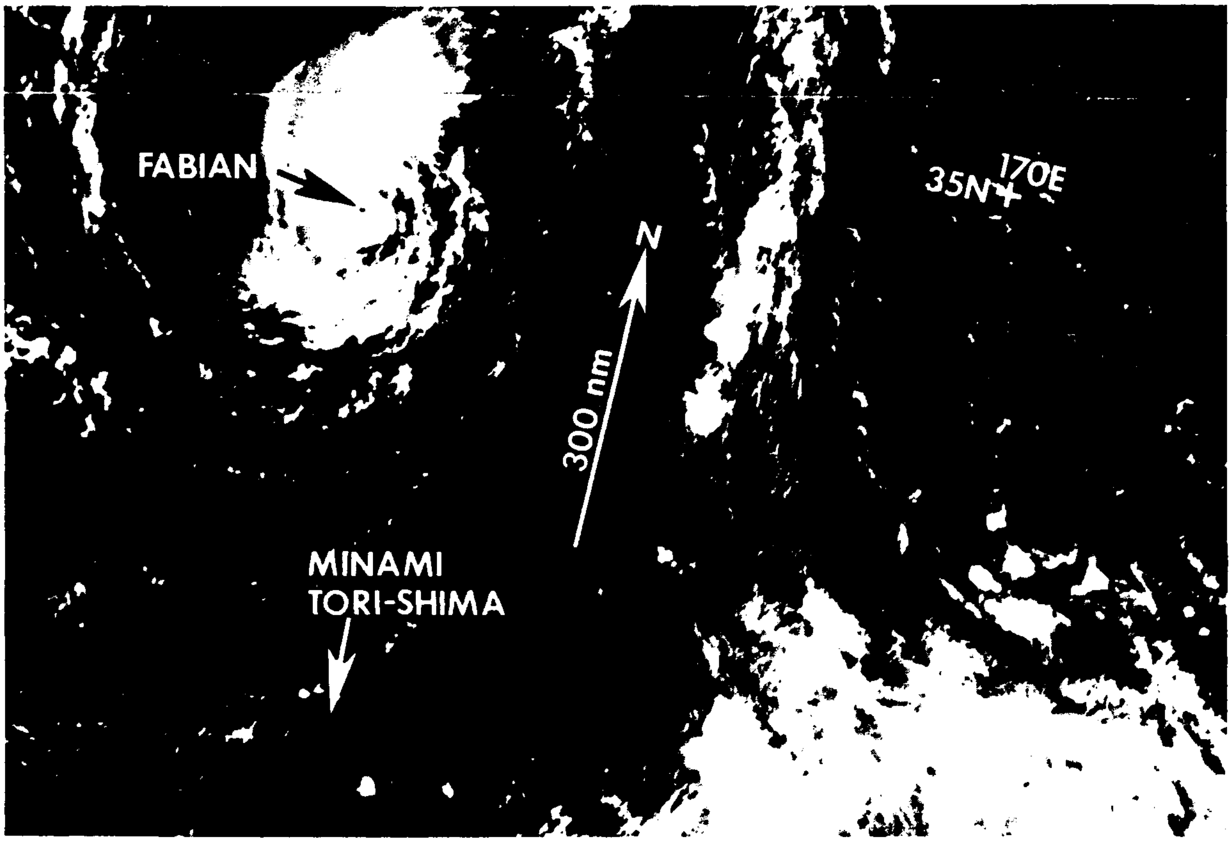
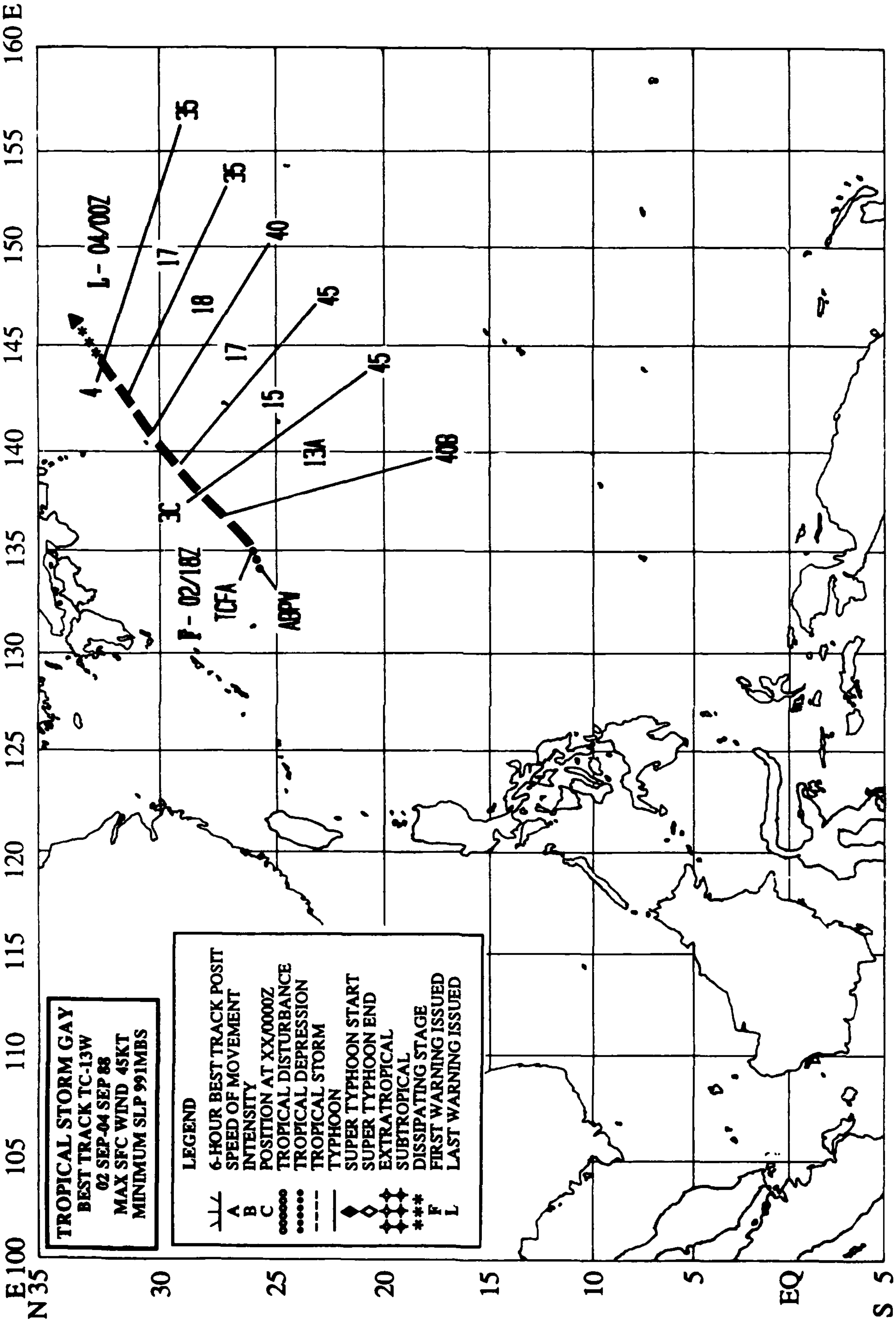


Figure 3-11/12-5. Fabian nearing peak intensity. Elsie has moved off the picture to the northeast of Fabian (312220Z August DMSP visual imagery).

Intentionally left blank.



TROPICAL STORM GAY
BEST TRACK TC-13W
02 SEP-04 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 04/00Z
F - 02/18Z
TCFA
ABPW

TROPICAL STORM GAY (13W)

Gay was a short-lived (two day) tropical cyclone. Only six warnings were issued on the system before it dissipated over water. The disturbance that eventually became Gay formed in the monsoon trough 420 nm (778 km) east of Okinawa. It was first mentioned on the Significant Tropical Weather Advisory at 020600Z and rated as having a "fair" potential for significant development. The system's convection rapidly increased in amount and became better organized when its low-level circulation moved beneath the divergent area ahead of an approaching upper-level trough. After synoptic data (020600Z) indicated the disturbance had sustained surface winds in the 20 to 30 kt (10 to 15 m/sec) range and satellite wind estimates of 35 kt (18 m/sec), a Tropical Cyclone Formation Alert was issued at 021040Z. The first warning (021800Z) on Tropical Storm Gay followed. Gay moved northeastward at speeds of 14 kt (26 km/hr), or more, and reached a peak intensity of 45 kt (23 m/sec) sustained surface winds (Figure 3-13-1). After peaking, the tropical cyclone tracked into an environment of strong vertical wind shear, which separated the system's deep convection from its low-level circulation. The final warning was issued on Gay at 040000Z while it was dissipating over water 290 nm (537 km) southeast of Tokyo.

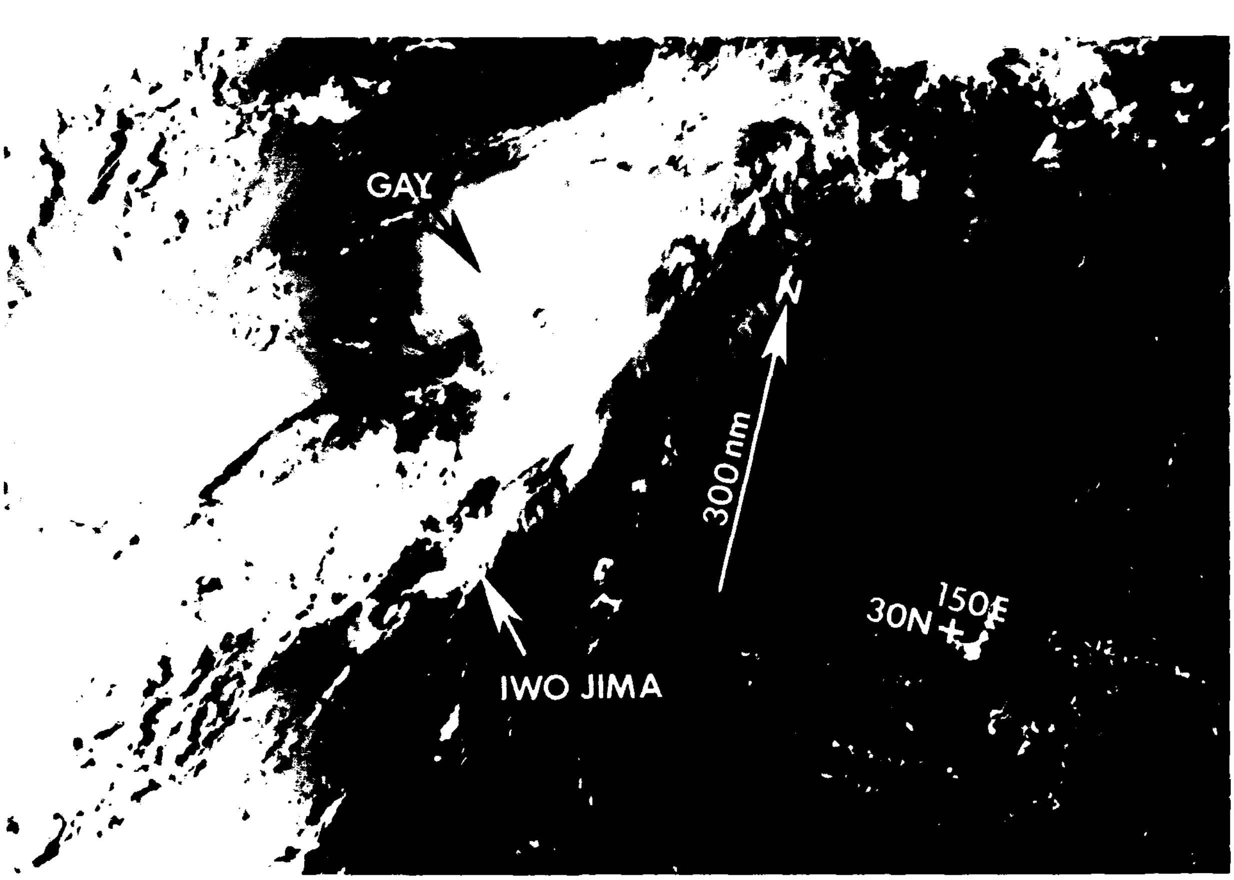
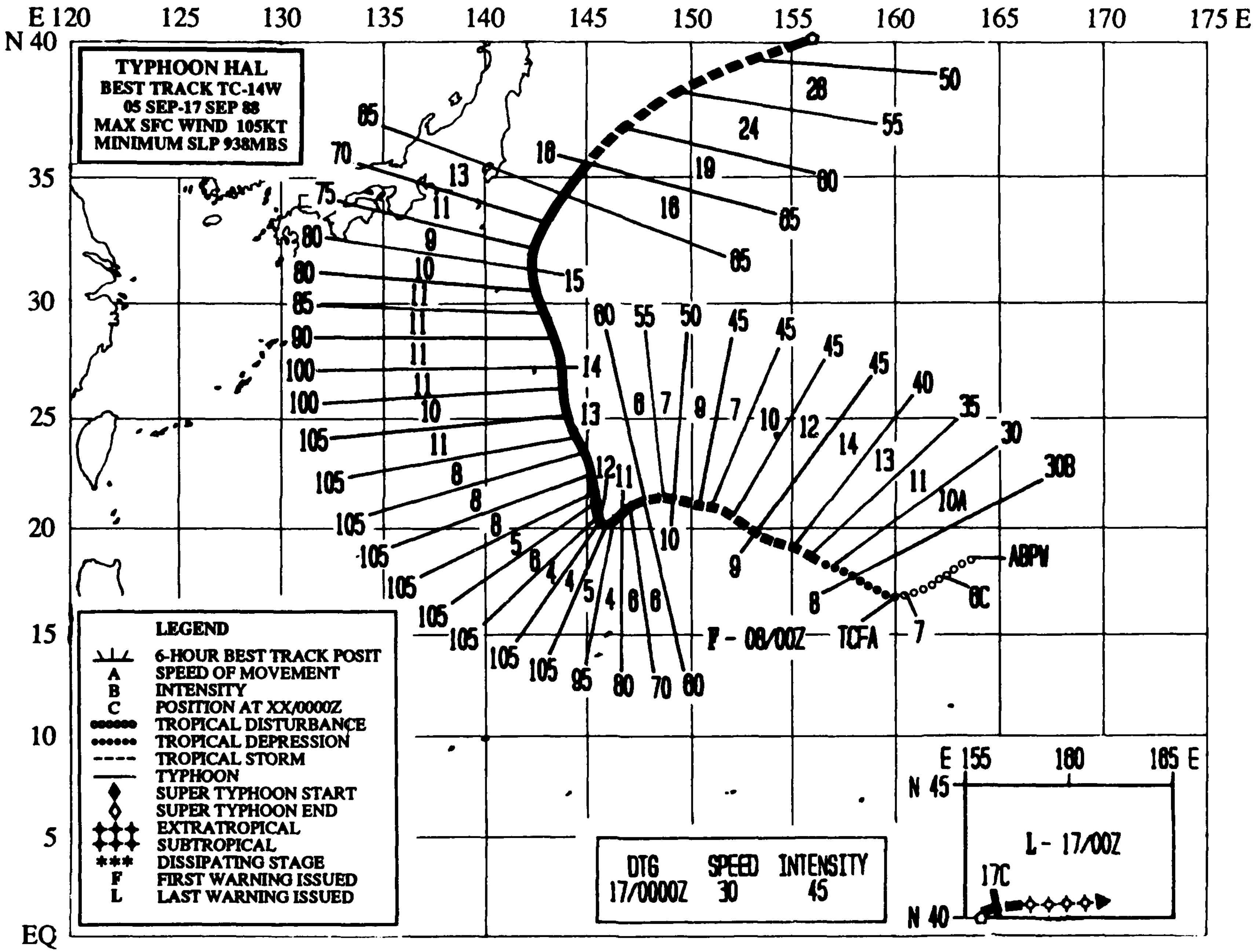


Figure 3-13-1. Tropical Storm Gay at peak intensity (030605Z September NOAA visual imagery).


TYPHOON HAL
BEST TRACK TC-14W
05 SEP-17 SEP 88
MAX SFC WIND 105KT
MINIMUM SLP 938MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
DTG SPEED INTENSITY
17/0000Z 30 45
F - 08/00Z
TCFA
ABPW
L - 17/00Z
17C
E 120
175 E
N 40
EQ

TYPHOON HAL (14W)

Typhoon Hal was the second of eight significant tropical cyclones and the first of two typhoons to form in the western North Pacific during September. Hal combined with Typhoon Uleki (01C), Tropical Storm Irma (15W), and later with Tropical Storm Jeff (16W) to create the first three-storm situations of 1988 in the western North Pacific.

On 5 September the remnants of Gay (13W) dissipated east of Japan. In the central North Pacific Uleki (01C) churned west-northwestward from Hawaii and a large tropical upper-tropospheric trough (TUTT) low was situated northwest of Wake Island. Hal formed just west of Wake Island as a tropical disturbance induced by this TUTT low. At 050600Z, the system was first mentioned on the Significant Tropical Weather Advisory. Over the next two days, the disturbance moved westward along the southern side of the subtropical ridge and became more organized. This growth prompted a Tropical Cyclone Formation Alert at 070430Z. Hal continued to organize. At 080000Z, the Alert was superseded by the first warning on Tropical Depression 14W, then upgraded (081200Z) to Tropical Storm Hal (Figure 3-14-1), when satellite intensity analysis indicated sustained surface winds of 35 kt (18 m/sec). Initially, Hal tracked west-southwestward, but eventually settled into a west-northwestward track as the subtropical ridge to its north weakened slightly. Hal continued to intensify and, at 101800Z, reached typhoon intensity.

Earlier at 101200Z, when Hal was 120 nm (222 km) northeast of Maug in the northern

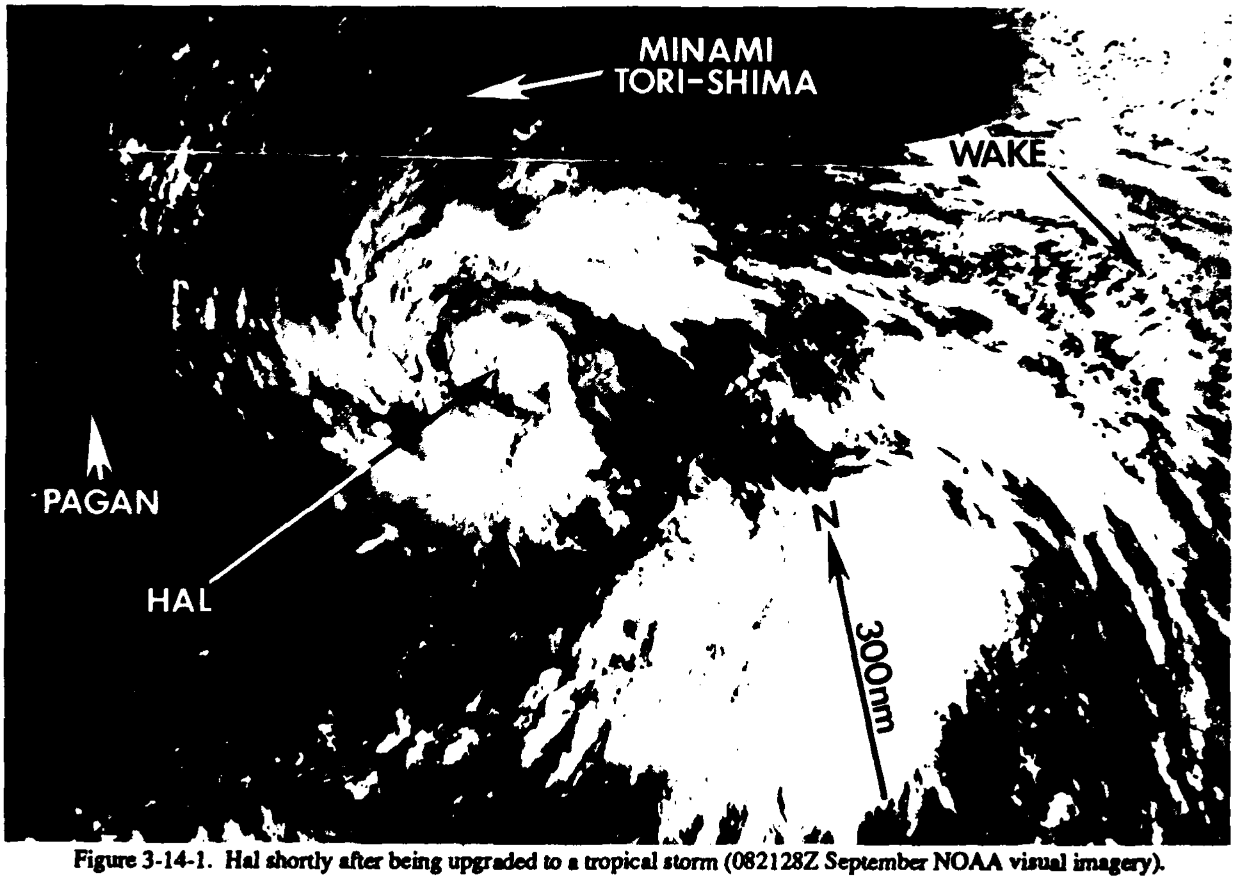


Figure 3-14-1. Hal shortly after being upgraded to a tropical storm (082128Z September NOAA visual imagery).

Marianas, the tropical cyclone started to decelerate and track to the southwest in response to stronger ridging to its north and west. After Typhoon Hal reached its peak intensity of 105 kt (54 m/sec) at 111200Z, it continued onward and passed over Maug, which is uninhabited, at 111800Z. On Guam (WMO 91212), 395 nm (732 km) to the south, the enhanced southwesterly inflow into Hal brought brisk surface winds with gusts to 40 kt (20 m/sec). Power outages and minor property damage were reported on the islands of Guam and Saipan.

With a mid-latitude trough creating lower pressure-heights in the subtropical ridge north of the typhoon, Hal's direction of track changed to the north-northwest. Japan braced for the possibility of being affected by three tropical cyclones: Typhoon Hal (Figure 3-14-2), plus Tropical Storms Irma (15W) and Jeff (16W), which had developed southeast and southwest, respectively. During the next three days, Hal weakened, developed a large 60 nm

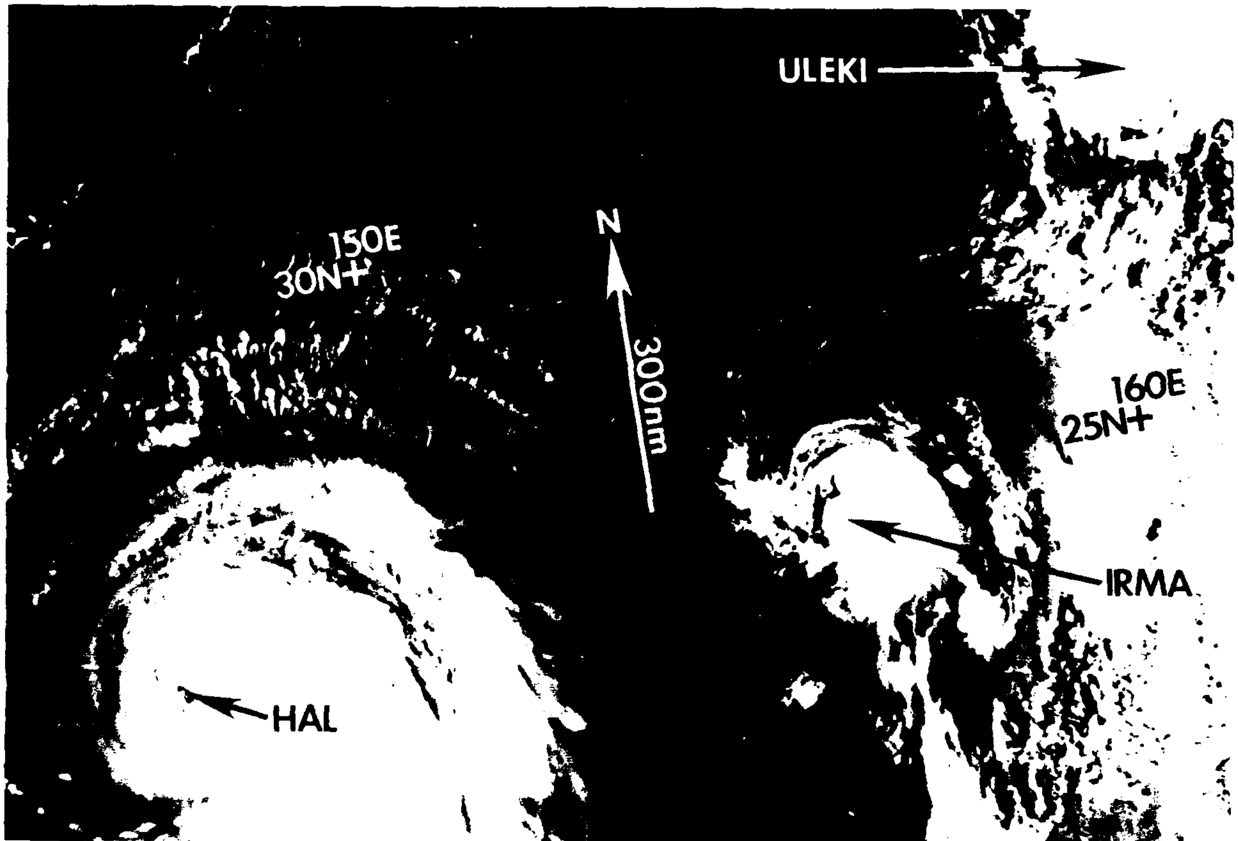


Figure 3-14-2. Typhoon Hal, at peak intensity. Also visible are Tropical Storms Irma (15W) and Uleki (01C) (122141Z September NOAA visual imagery).

(111 km) diameter eye and continued moving north-northwestward. At 150000Z, Hal (Figure 3-14-3) approached 32 degrees North latitude, started to recurve and accelerate. Typhoon Hal further weakened to 65 kt (33 m/sec) and made its closest point of approach - 195 nm (361 km) - to Tokyo, Japan at 151800Z. High surf caused several deaths and injuries along the coastal areas near Tokyo.

As Hal moved off to the northeast, its central convection was stripped away from its low-level circulation center by strong mid-latitude westerlies. When the final warning was issued at 170000Z, the system had weakened to 45 kt (23 m/sec), increased forward speed to 32 kt (59 km/hr) and was extratropical.

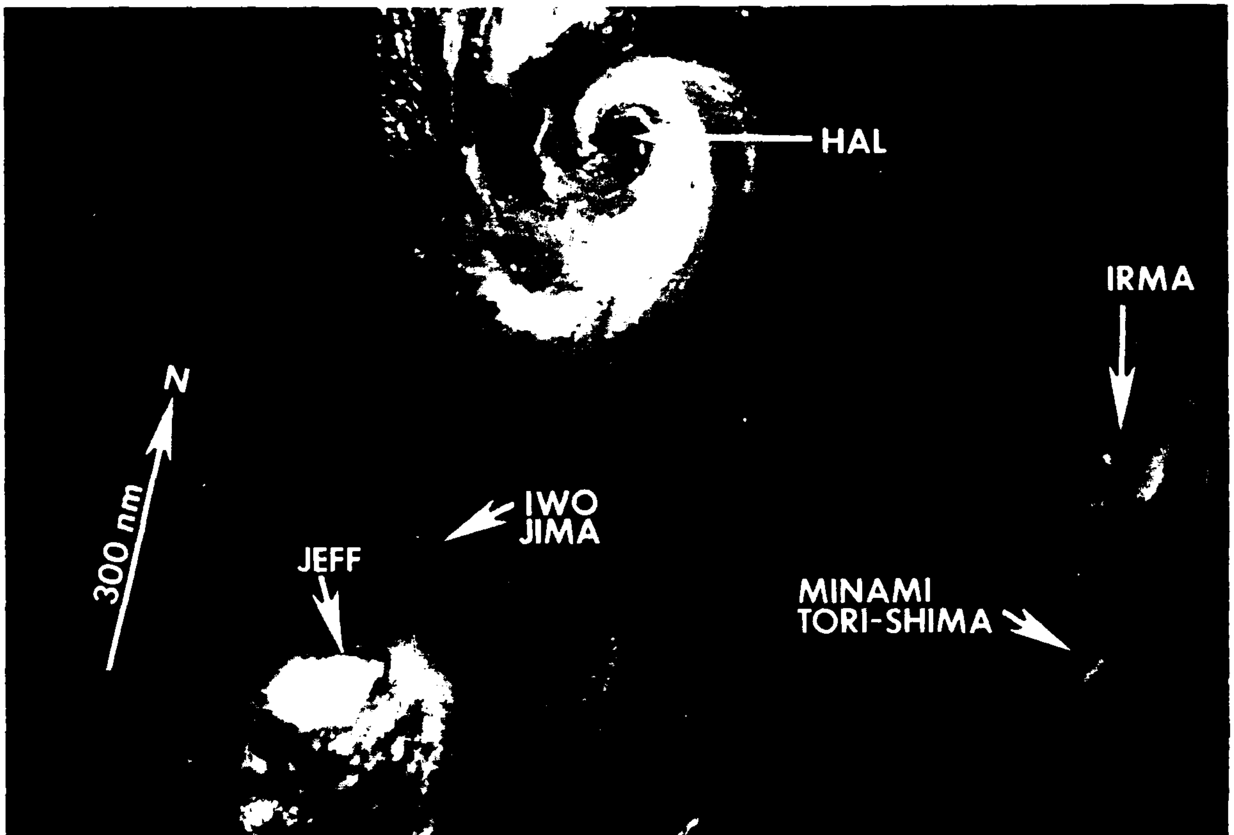
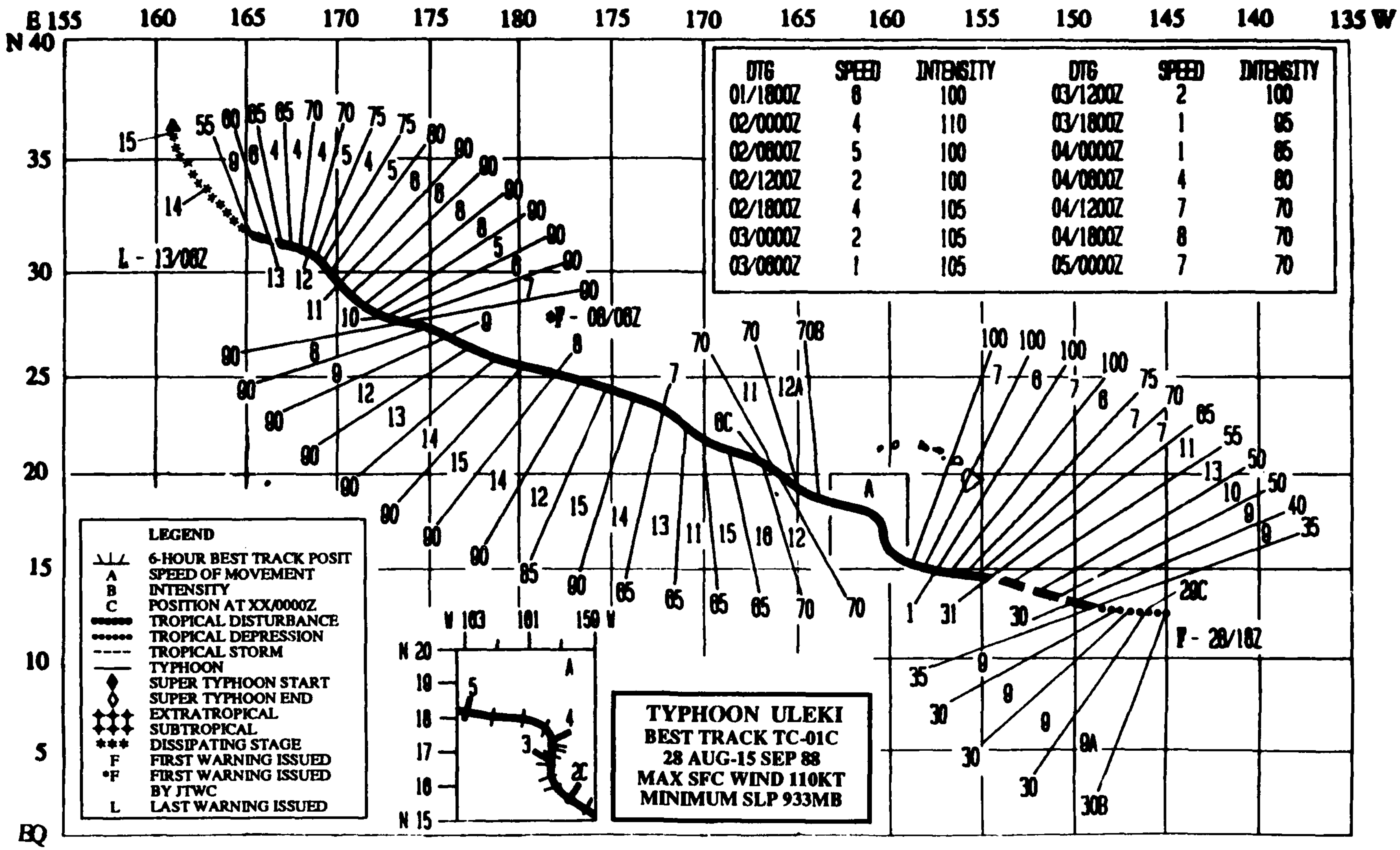


Figure 3-14-3. Typhoon Hal, Tropical Storms Irma (15W) and Jeff (16W) (150936Z September NOAA infrared imagery).


TYPHOON ULEKI
BEST TRACK TC-01C
28 AUG-15 SEP 88
MAX SFC WIND 110KT
MINIMUM SLP 933MB
DTG SPEED INTENSITY
01/1800Z 8 100
02/0000Z 4 110
02/0600Z 5 100
02/1200Z 2 100
02/1800Z 4 105
03/0000Z 2 105
03/0600Z 1 105
DTG SPEED INTENSITY
03/1200Z 2 100
03/1800Z 1 85
04/0000Z 1 85
04/0600Z 4 80
04/1200Z 7 70
04/1800Z 8 70
05/0000Z 7 70
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
•F FIRST WARNING ISSUED BY JTWC
L LAST WARNING ISSUED
L - 13/06Z
•F - 08/06Z
F - 28/18Z
E 155
160
165
170
175
180
175
170
165
160
155
150
145
140
135 W
N 40
35
30
25
20
15
10
5
EQ

TYPHOON ULEKI (01C)

Uleki was only the third hurricane (Sarah (1967) and Peke (1987) were the previous two) in the past thirty years to form in the eastern North Pacific Ocean and cross the international dateline while in a warning status. Uleki tracked over 3,300 nm (6,105 km) during its eighteen day life span.

Uleki was first detected by the Central Pacific Hurricane Center (CPHC) at 281800Z August. During the next four days, Uleki tracked westward and intensified. CPHC's warnings were disseminated to military customers by the Naval Western Oceanography Center (NWOC). At 291800Z, Uleki had reached tropical storm intensity and was upgraded to a hurricane at 310000Z. The tropical cyclone slowed its forward motion and continued to intensify until 2 September, when it reached a peak intensity of 110 kt (57 m/sec). As Uleki approached the Hawaiian Islands, weather reconnaissance aircraft joined with satellite reconnaissance to watch the hurricane. At peak intensity, the direction of movement changed from west-northwestward to northward. Uleki headed directly towards the island of Oahu. The hurricane approached to within 270 nm (500 km) of Honolulu at 040000Z before changing course to the west-northwest and accelerating. The tropical cyclone began a weakening trend as it entered a shearing environment, and the upper-level outflow in the western semicircle became restricted. Uleki continued to move west-northwestward and approached the international dateline (Figure 3-01C-1). It appeared that

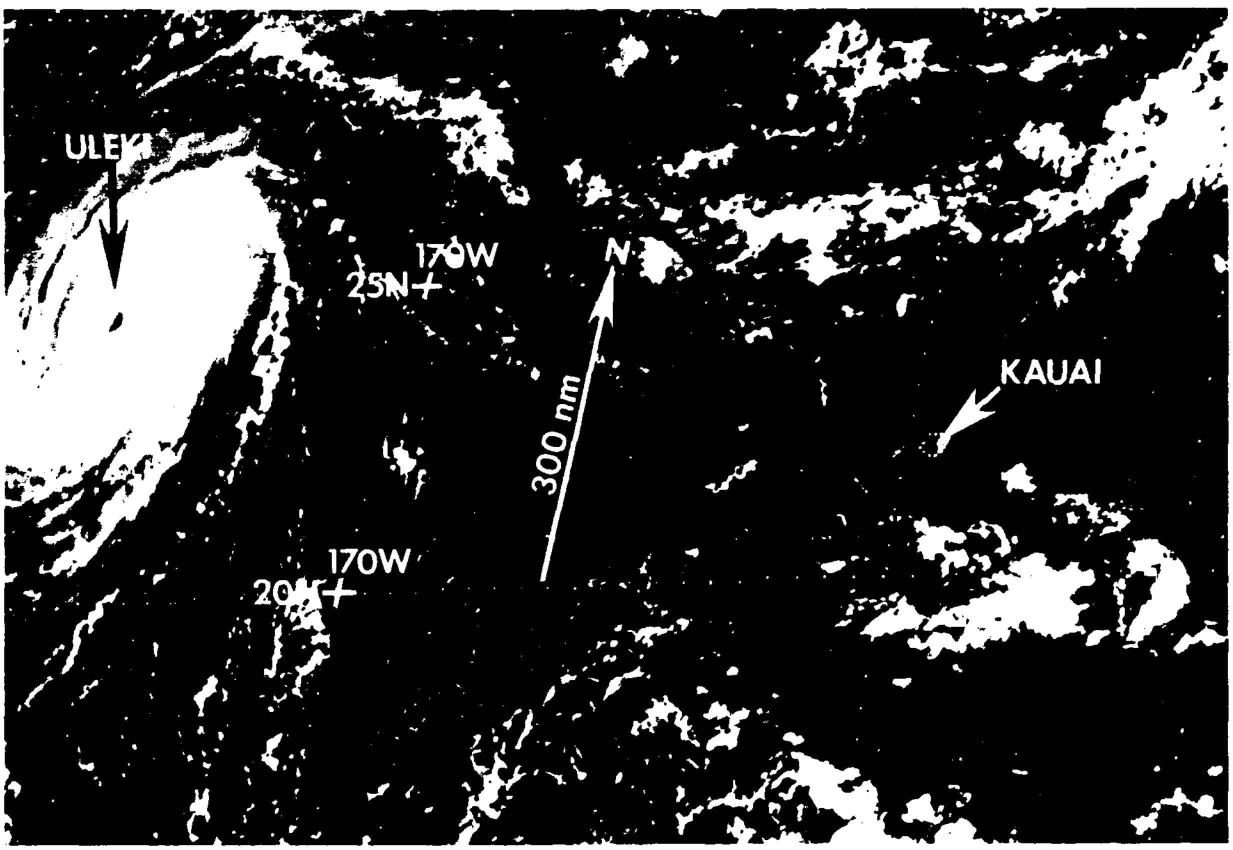


Figure 3-01C-1. Hurricane Uleki heads towards the international dateline. Note the distinct shadow on the eye wall caused by the low sun angle. The Hawaiian Islands are visible to the east of Uleki. Photo courtesy of the National Weather Service Forecast Office, Honolulu, Hawaii (071846Z September GOES West visual imagery).

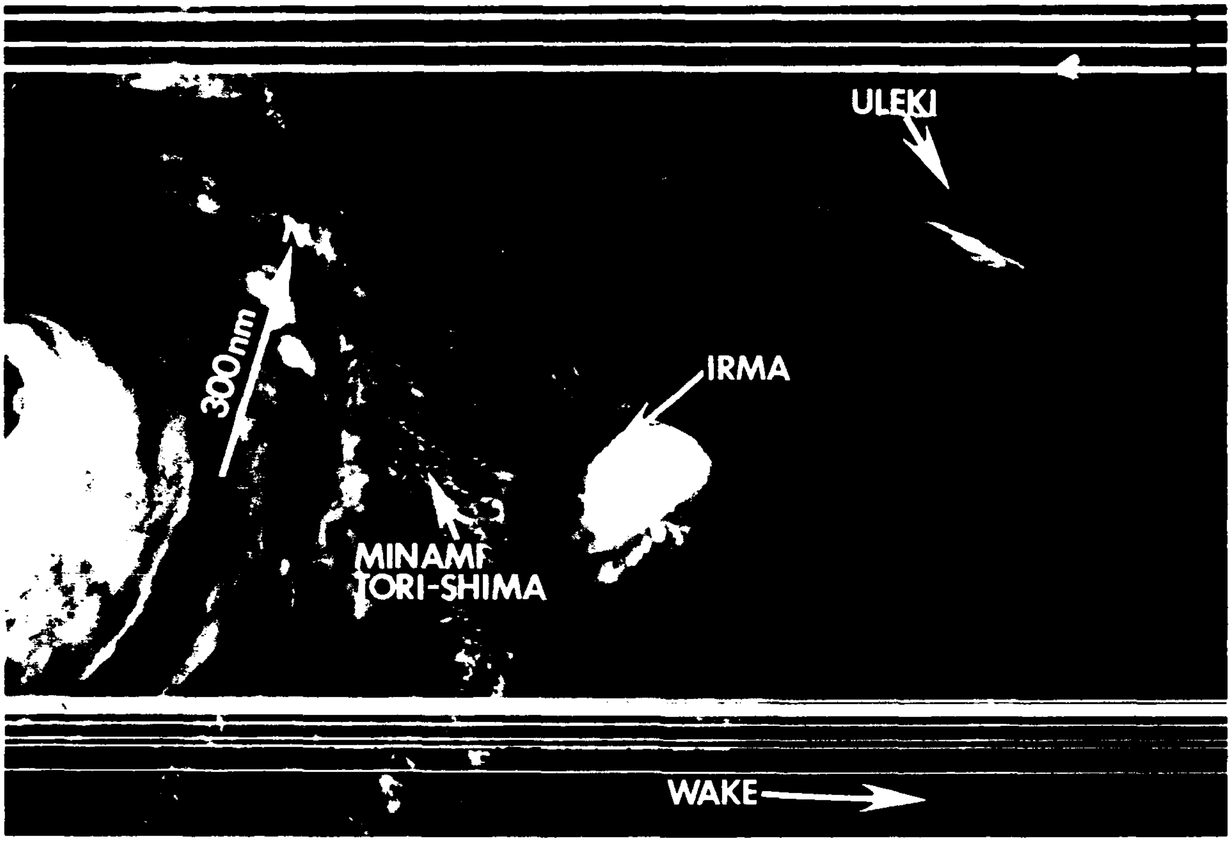


Figure 3-01C-2. Uleki, shortly after the final warning (130839Z September NOAA infrared imagery).

Uleki would be exiting CPHC and NWOC's area of responsibility, and entering JTWC's area of responsibility after the 080000Z warning.

Warning responsibility was transferred for the 080600Z warning and JTWC issued its first warning on Uleki. The system was redesignated Typhoon Uleki. At this time the tropical cyclone had an intensity of 90 kt (46 m/sec). Uleki pressed onward to the west-northwest along the southern edge of a subtropical ridge, and gradually slowed. At 100600Z, the speed of movement had dropped from 15 kt (28 km/hr) to 6 kt (11 km/hr). The typhoon had entered the weak 700 mb steering flow in an area between two anticyclones in the subtropical ridge. With a mid-latitude trough approaching from the west, Uleki was forecast to recurve during the next 24- to 48-hours. The trough caused the tropical cyclone to "step climb" to the north-northwest, but was not able to bring about recurvature. Uleki returned to a northwestward track and weakened in response to increased vertical wind shear and entrainment of low-level cooler air. At 130000Z, strong vertical wind shear associated with a second trough caused the tropical cyclone to weaken rapidly and be downgraded to a tropical storm. Satellite imagery showed a long, narrow plume of cirrus streaming from Uleki to the northeast. The final warning was issued at 130600Z (Figure 3-01C-2) and at 140000Z, all of Uleki's deep convection had been sheared away to the northeast. The low-level circulation center persisted over water until 15 September (Figure 3-01C-3).

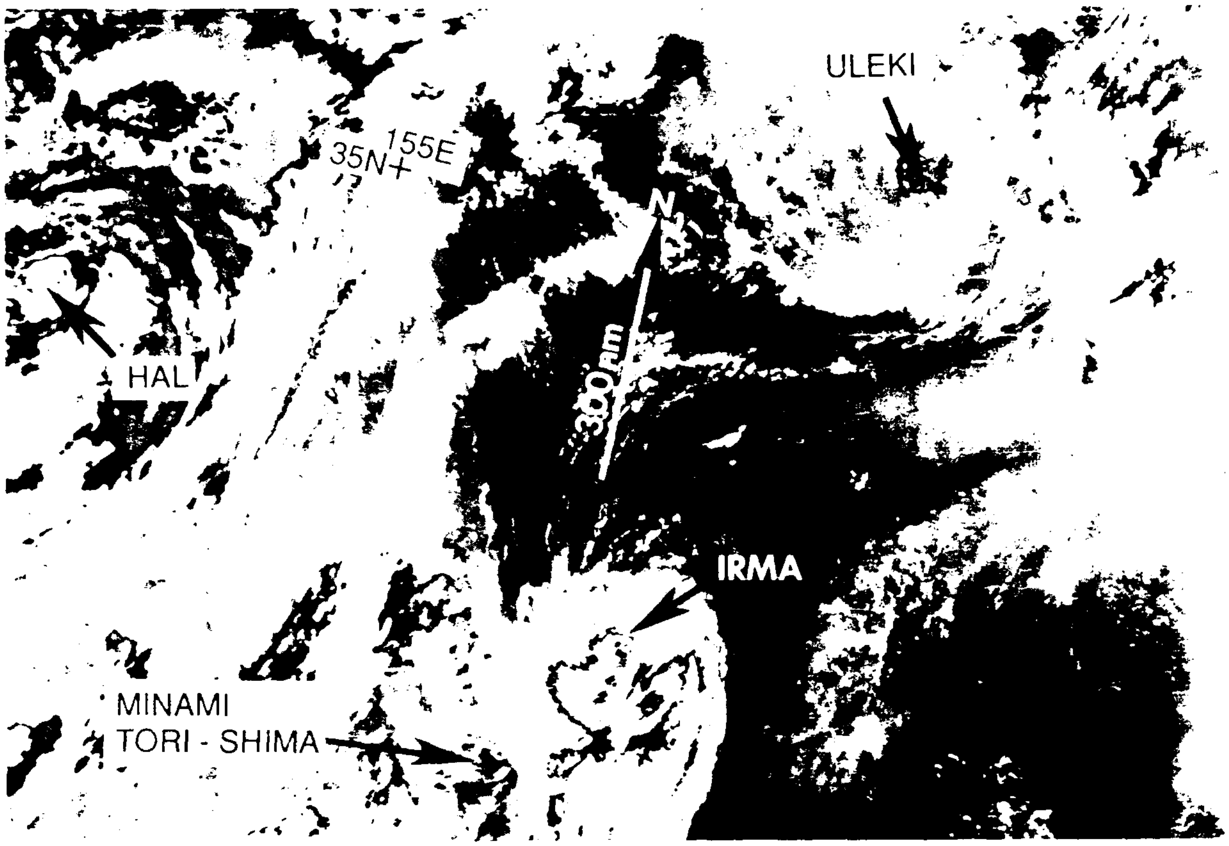
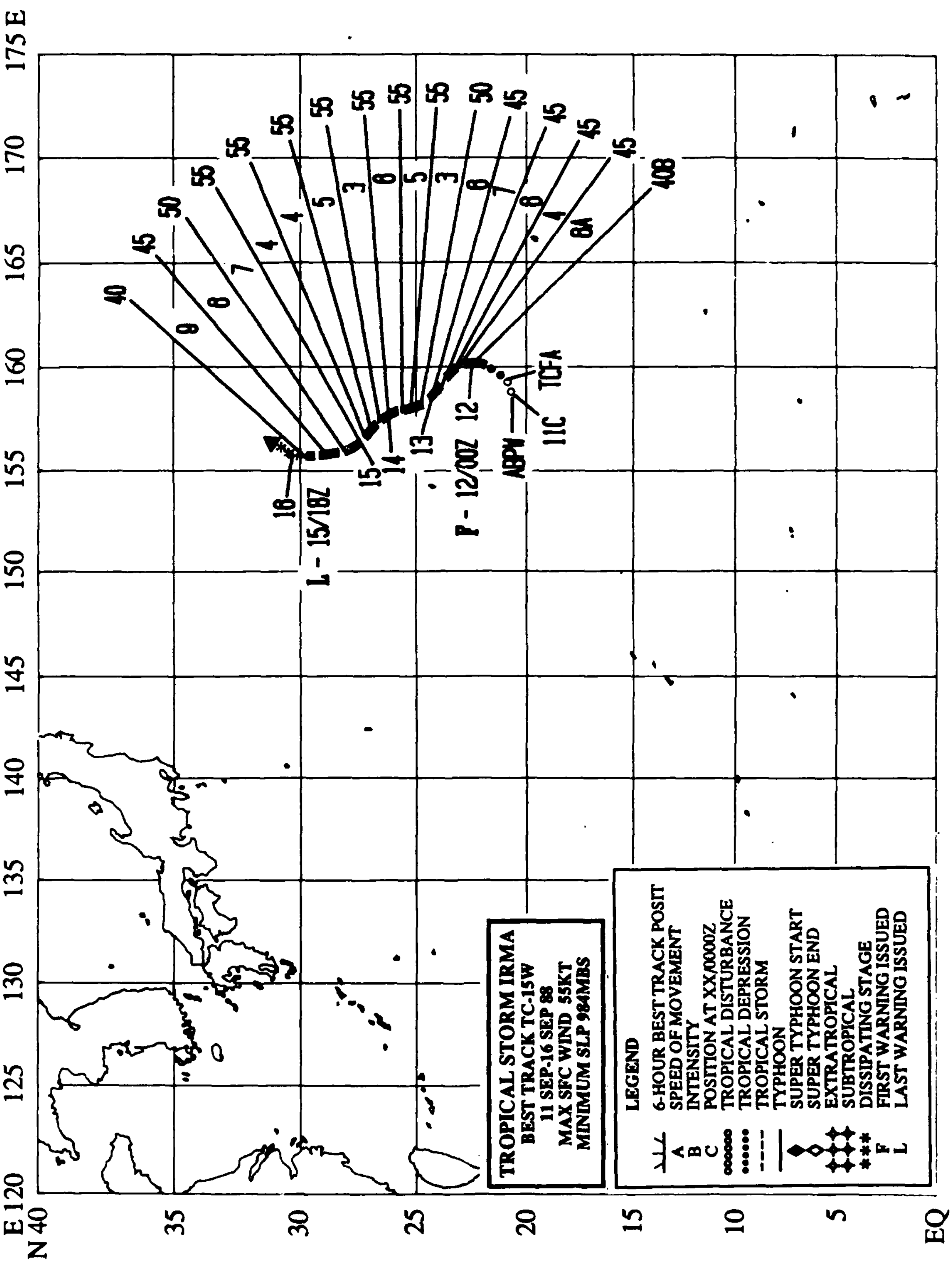
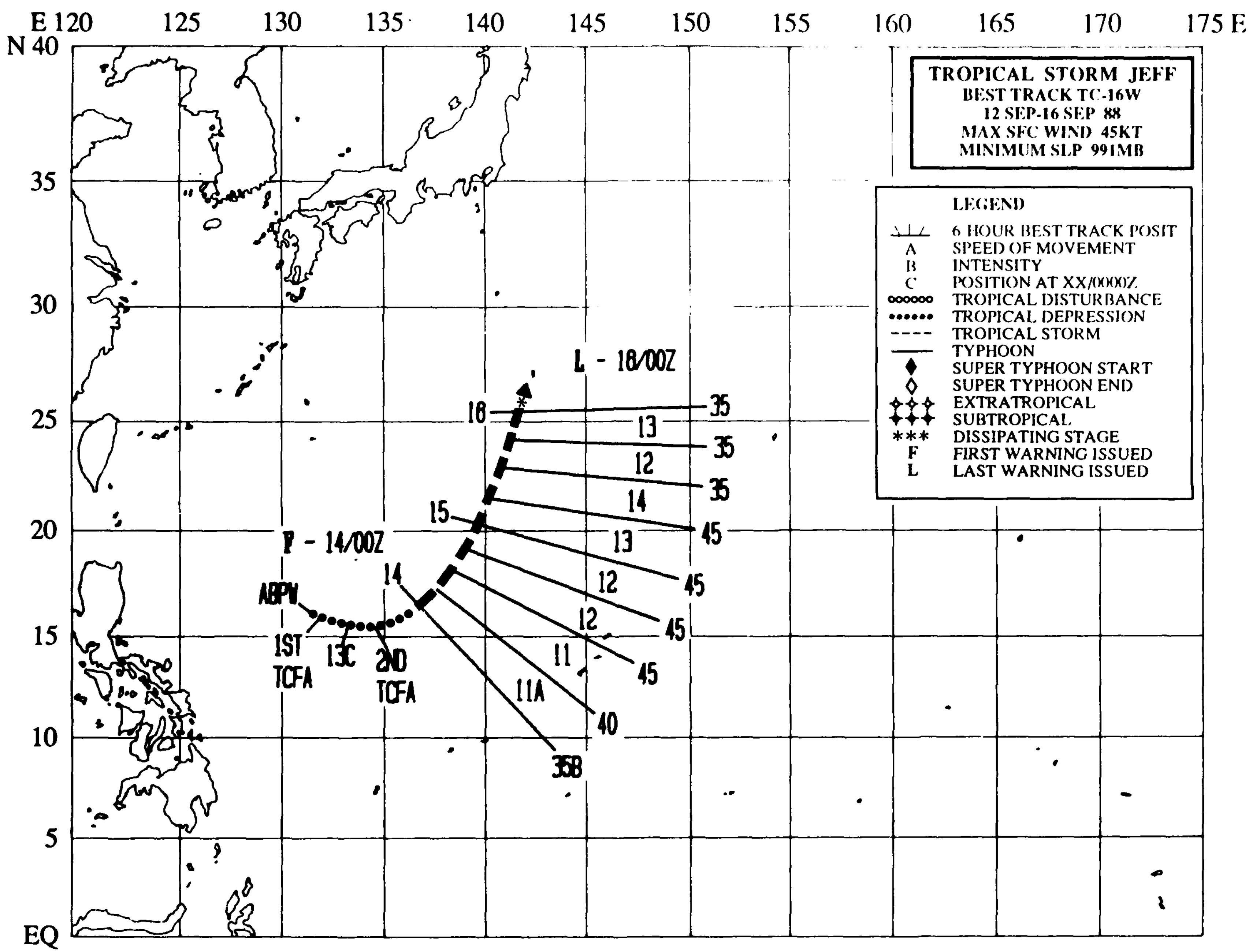


Figure 3-01C-3. Uleki dissipating over water (142247Z September DMSP infrared imagery).

Intentionally left blank.


TROPICAL STORM IRMA
BEST TRACK TC-15W
11 SEP-16 SEP 88
MAX SFC WIND 55KT
MINIMUM SLP 984MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 15/18Z
F - 12/00Z
ABPW
TCFA
11C
12
13
14
15
16


TROPICAL STORM JEFF
BEST TRACK TC-16W
12 SEP-16 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 16/00Z
F - 14/00Z
ABPW
1ST TCFA
13C
2ND TCFA
14
15
16
35B
11A
40
11
45
12
45
12
45
13
45
14
35
12
35
13
35
E 120
125
130
135
140
145
150
155
160
165
170
175 E
N 40
35
30
25
20
15
10
5
EQ

TROPICAL STORM IRMA (15W) AND TROPICAL STORM JEFF (16W)

Irma and Jeff, circulations spawned by enhanced inflow into Typhoon Hal (14W), never achieved typhoon intensity. Both were part of multiple tropical cyclone outbreaks of 12 to 16 September and sheared away when Hal (14W) moved northward through the subtropical ridge.

By the second week of September Hal (14W), which started earlier as a tropical upper-tropospheric trough (TUTT) induced system, had matured south of the subtropical ridge and developed a large supporting low-level southwesterly inflow. (This inflow was separated from, and not the normal eastward extension of, the Asian southwest monsoon.) Jeff formed at the extreme western end and Irma at the extreme eastern end of this southwesterly inflow.

Compared to Jeff, Irma got a head start in central convection and was first noted on the Significant Tropical Weather Advisory at 110000Z. Although the outflow from Hal (14W) to the west streamed across the area, Irma persisted. This increased convective

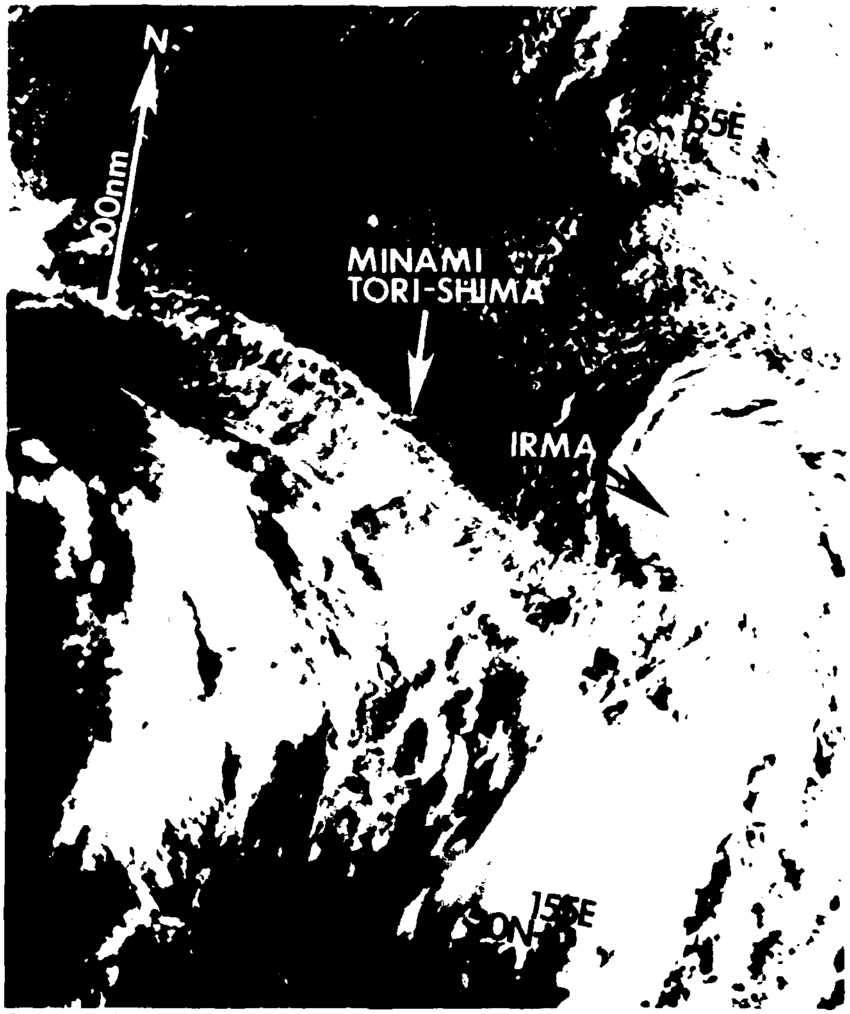


Figure 3-15/16-1. Irma about four hours before the first warning (111946Z September DMSP visual imagery).

activity (Figure 3-15/16-1) required a Tropical Cyclone Formation Alert at 110920Z and a first warning, based on a satellite intensity estimate of 40 kt (21 m/sec), at 120000Z.

Meanwhile, Jeff consolidated and was included on the 120600Z Advisory. Organization of the convection continued and ' :: Alert followed at 121200Z. Another Alert was issued at 131030Z before a 35 kt (18 m/sec) satellite surface wind estimate precipitated the first warning at 140000Z. Jeff's relatively slow development was related to its upper-level outflow being severely restricted in the northeast quadrant by the larger outflow from Hal (14W) to the northeast. This shear in the vertical, in fact, confined Jeff's central convection to the southern half of its low-level circulation for the lifetime of the system.

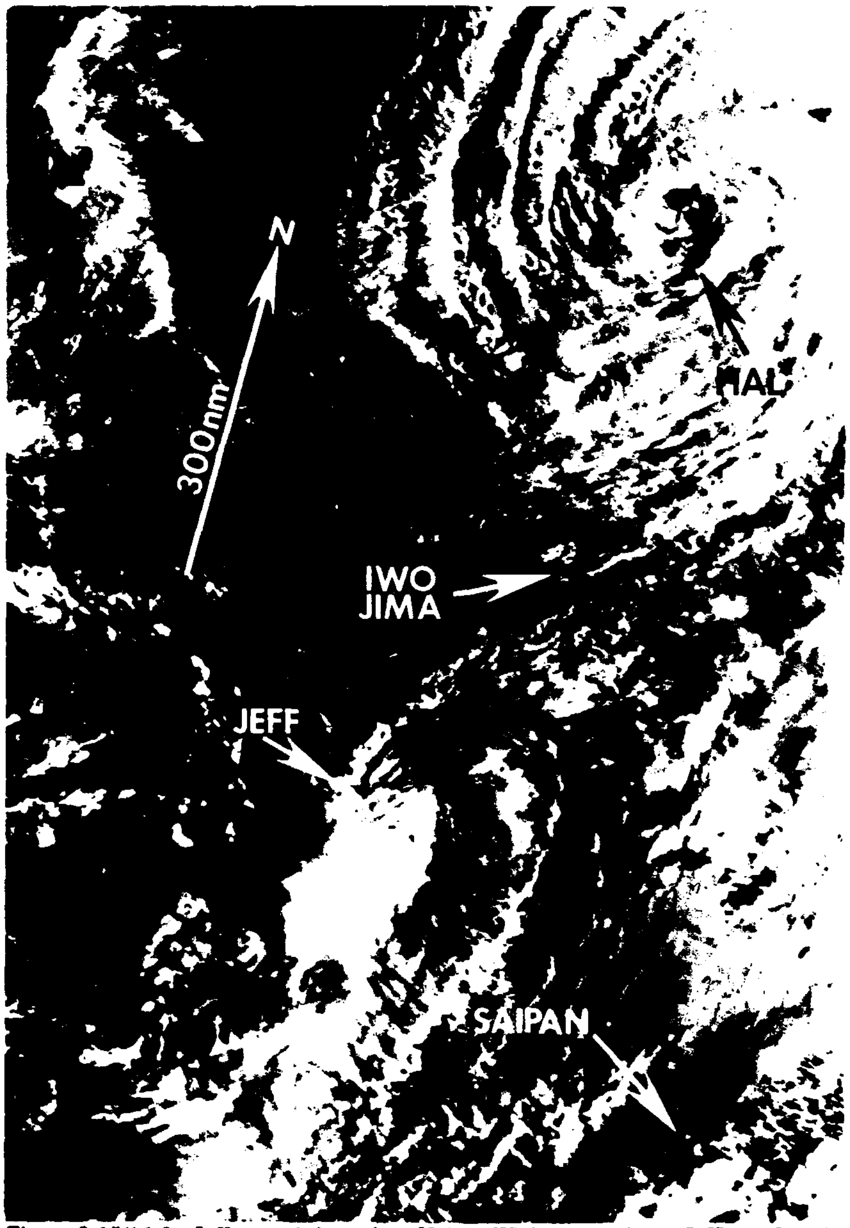


Figure 3-15/16-2. Jeff at peak intensity. Hal (14W) is at top right. Jeff's outflow is severely restricted to the north and east (142051Z September DMSP visual imagery).

Briefly, Jeff (Figure 3-15/16-2) reached a peak intensity of 45 kt (23 m/sec) on 14 September before gradually weakening. In contrast, Irma, which was aided by troughing in Hal's (14W) upper-level outflow, attained 55 kt (28 m/sec) at 131200Z half a day earlier and maintained that intensity through 0000Z on 15 September. Later, both Jeff and Irma were finalled within six hours of each other - Irma (Figure 3-15/16-3) at 151800Z and Jeff at 160000Z - as Hal (14W) moved northward through the subtropical ridge.

The relationship between the three tropical cyclones and the subtropical ridge is of interest. Earlier on 12 September, as Hal (14W) tracked to the north, the subtropical ridge segmented into two cells. These high pressure cells worked to narrow and restrict the low latitude inflow into Hal (14W). This appears to have affected the relative positions between Jeff, Irma and Hal (14W) (Figure 3-15/16-4). Initially, at 130000Z, the baseline (from A to B) between Jeff and Irma is relatively long compared to the height (from C to D) between Hal (14W) and the baseline. However, at

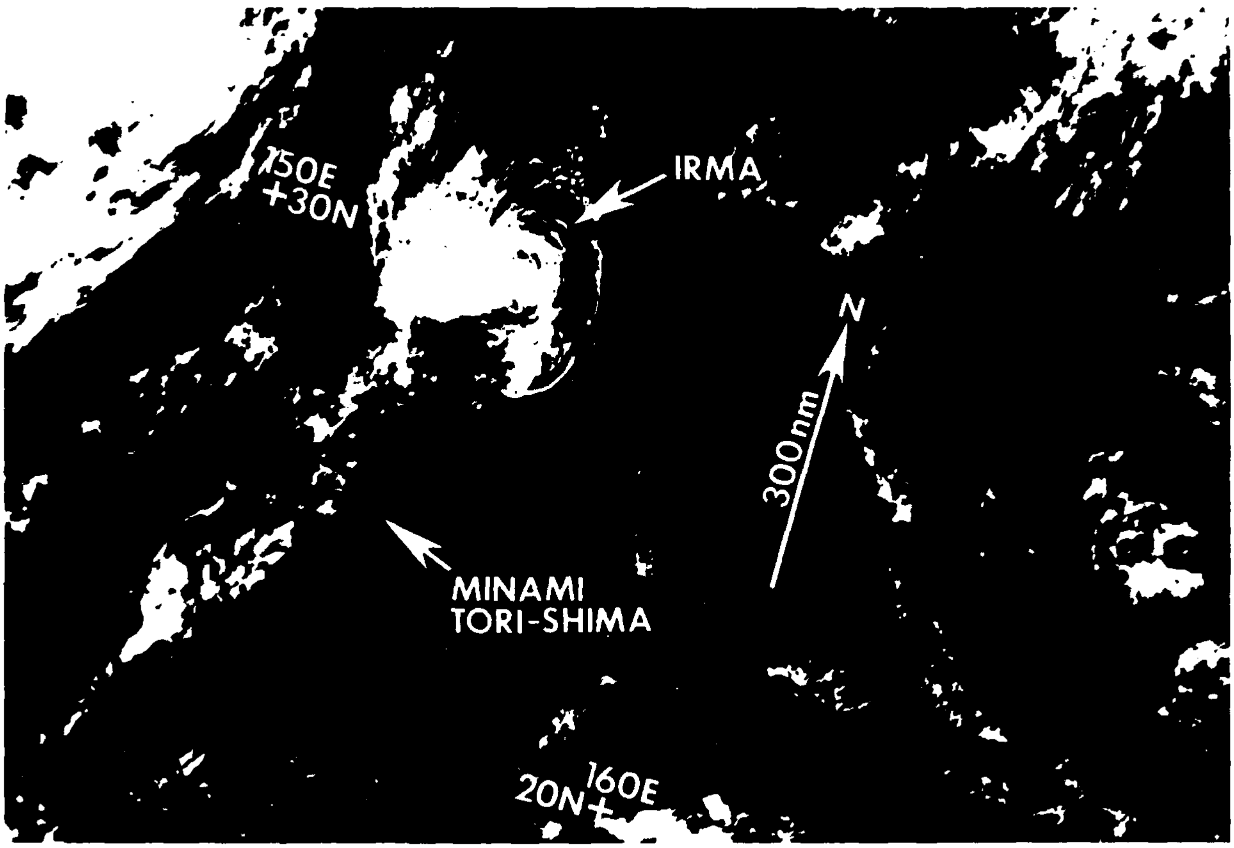


Figure 3-15/16-3. The low-level circulation is all that remains of Irma (152228Z September DMSP visual imagery).

160000Z the baseline has decreased to almost half its previous length and the height has more than doubled. These triangles (Figure 3-15/16-4) suggest a subtle tertiary interaction between Hal (14W) and the two smaller tropical cyclones in an almost non-divergent flow.

This multiple cyclone activity resulted in three sets of warnings being issued from 140000Z to 160000Z. Earlier, from 120000Z to 130600Z, Uleki (01C), Hal (14W) and Irma had required three sets of warnings. No damage reports were received for Jeff and Irma.

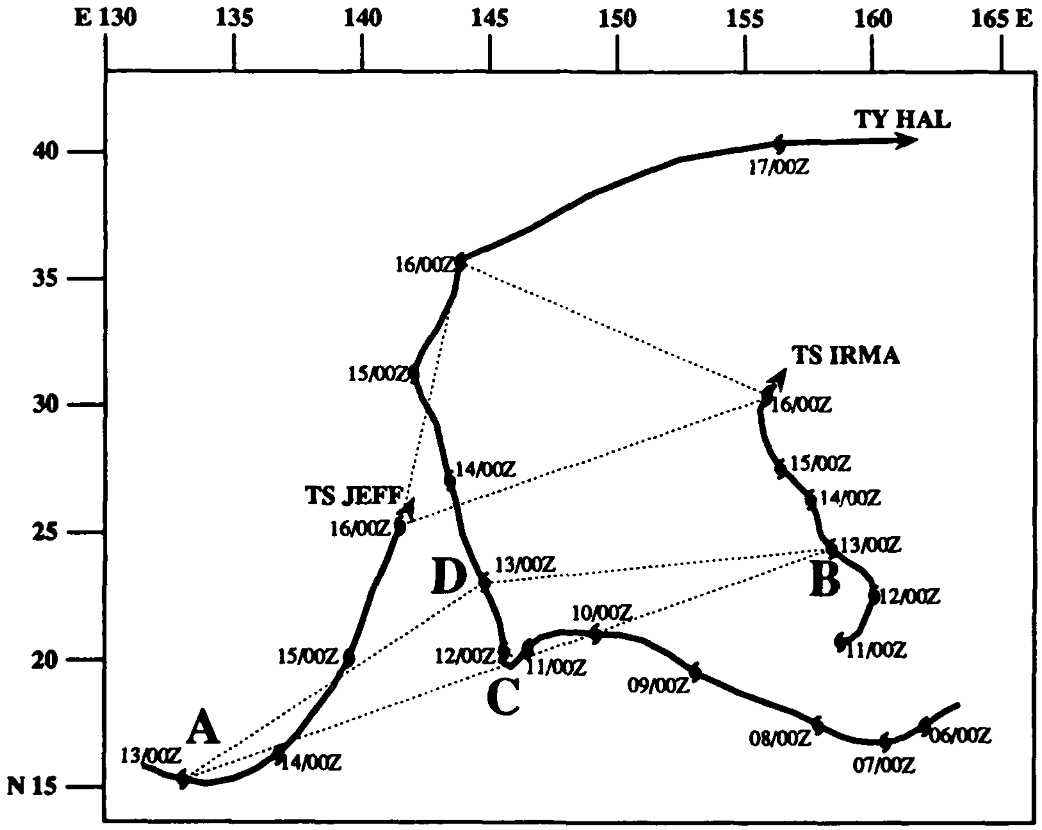
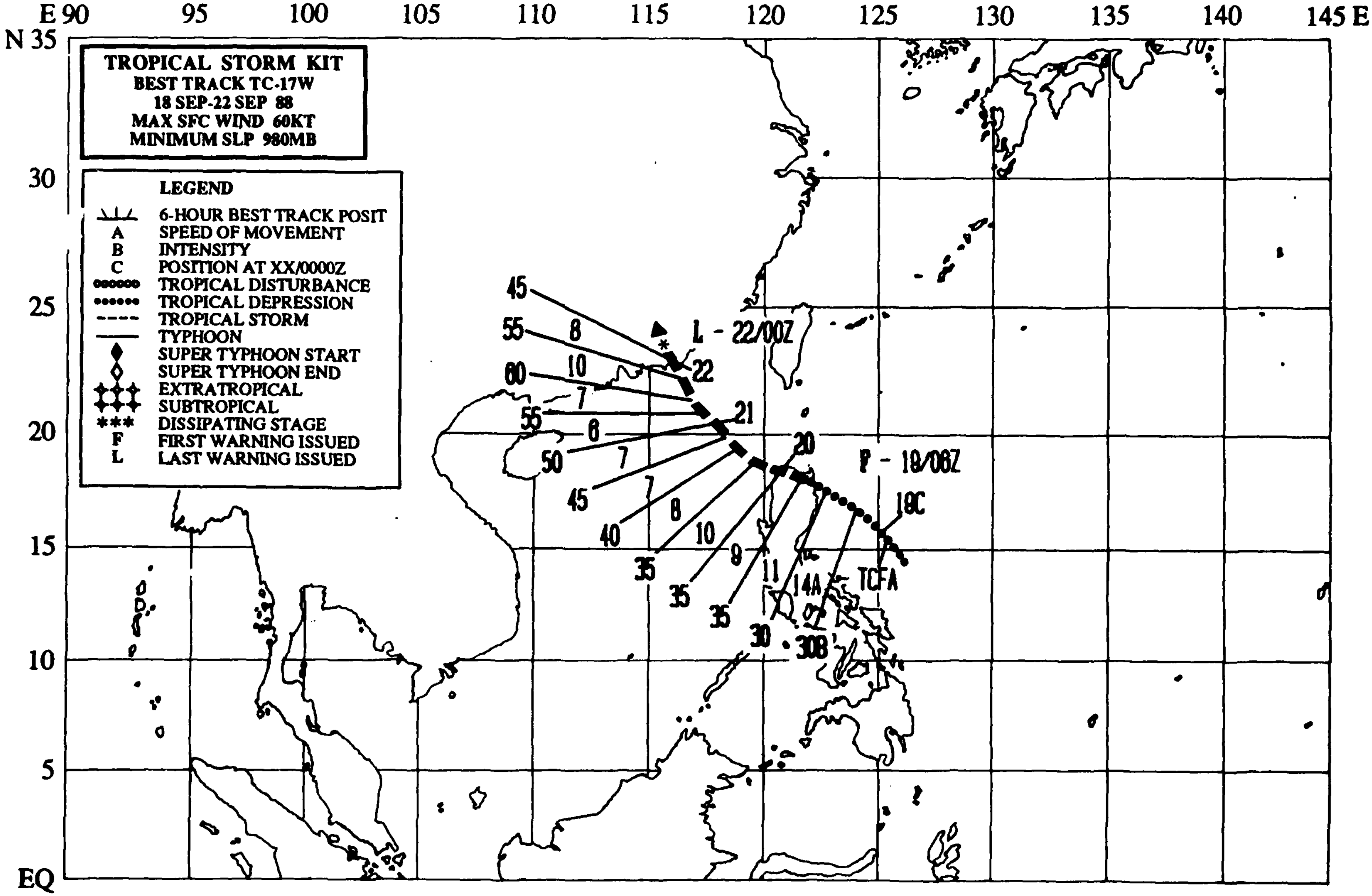


Figure 3-15/16-4. The tracks of Hal (14W), Irma and Jeff. Compare the length of the baseline (from A to B) between Jeff and Irma and the height, which is measured along the vertical (C to D) from the baseline to Hal (14W), at 130000Z with the second triangle at 160000Z. Note the relative adjustment of the three as Hal (14W) moves to the north.

Intentionally left blank.



TROPICAL STORM KIT
BEST TRACK TC-17W
18 SEP-22 SEP 88
MAX SFC WIND 60KT
MINIMUM SLP 980MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 22/00Z
F - 18/06Z
TCFA
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ

TROPICAL STORM KIT (17W)

Tropical Storm Kit was the sixth of eight significant tropical cyclones in September. It was a "straight runner" to the northwest and made landfall on the south coast of China. Kit caused loss of life and significant property damage in southeastern China.

The tropical cyclone was first detected on satellite imagery on 18 September 300 nm (556 km) east of Manila. The disturbance rapidly developed in the eastward extension of the monsoon trough and immediately became the subject of a Tropical Cyclone Formation Alert at 182230Z (Figure 3-17-1). Increased deep convection in the banding feature, improved outflow aloft, plus a satellite intensity

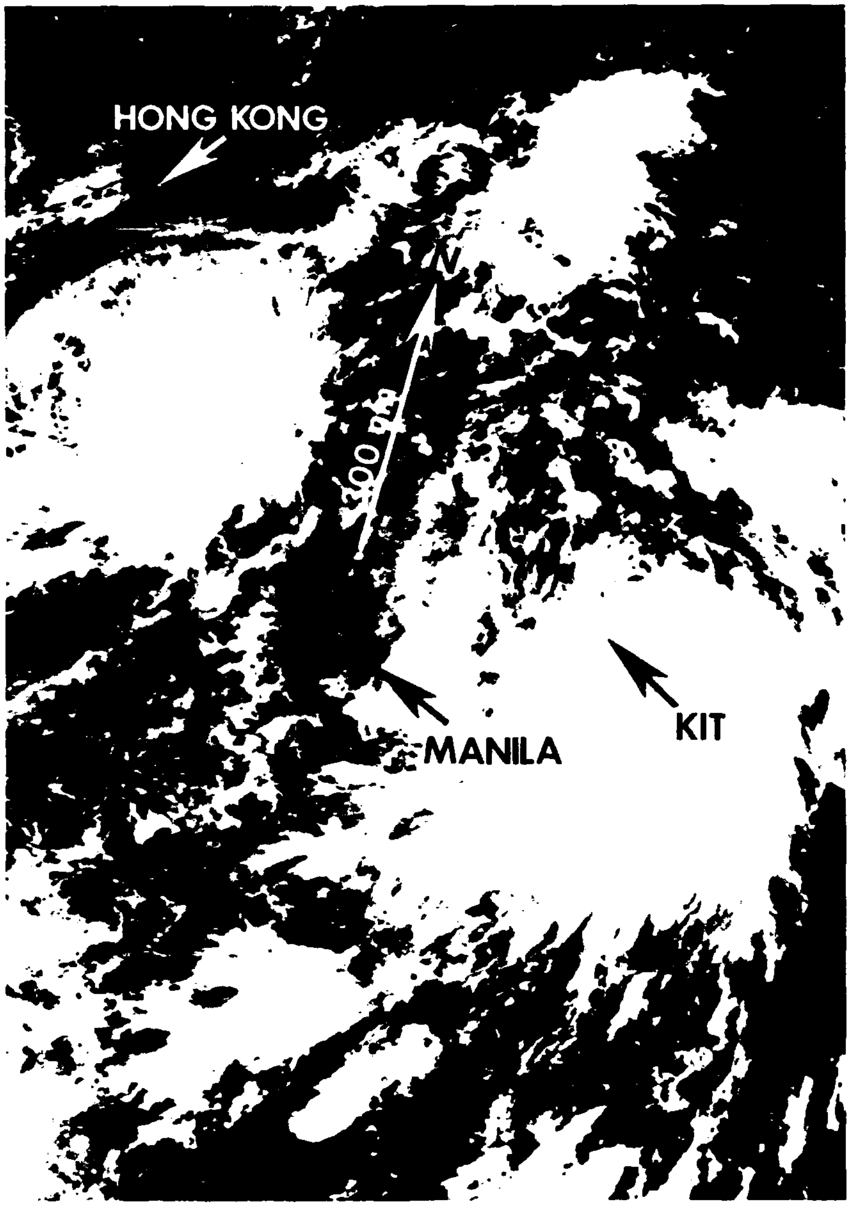


Figure 3-17-1. Kit as a tropical disturbance (190051Z September DMSP visual imagery).

estimate of sustained 30 kt (15 m/sec) surface winds, dictated the upgrade to Tropical Depression 17W at 090600Z.

Even though Kit tracked across the northern tip of Luzon, it continued to intensify. At 191800Z, another upgrade was needed — this time to tropical storm intensity. After being over land for six hours, it once again moved over open waters. The system developed a strong low-level inflow from the southwest and improved its upper-level outflow to the southeast through southwest (Figure 3-17-2). A day later, at 210600Z, Kit reached its peak intensity of 60 kt (31 m/sec).

After the intensity peaked, the tropical storm approached the coast of southern China and weakened. The final warning was issued on Kit at 220000Z, when it made landfall 120 nm (222 km) northeast of Hong Kong. Press releases from China indicated widespread flooding, loss of electrical power and at least three lives lost in the Guangdong province.

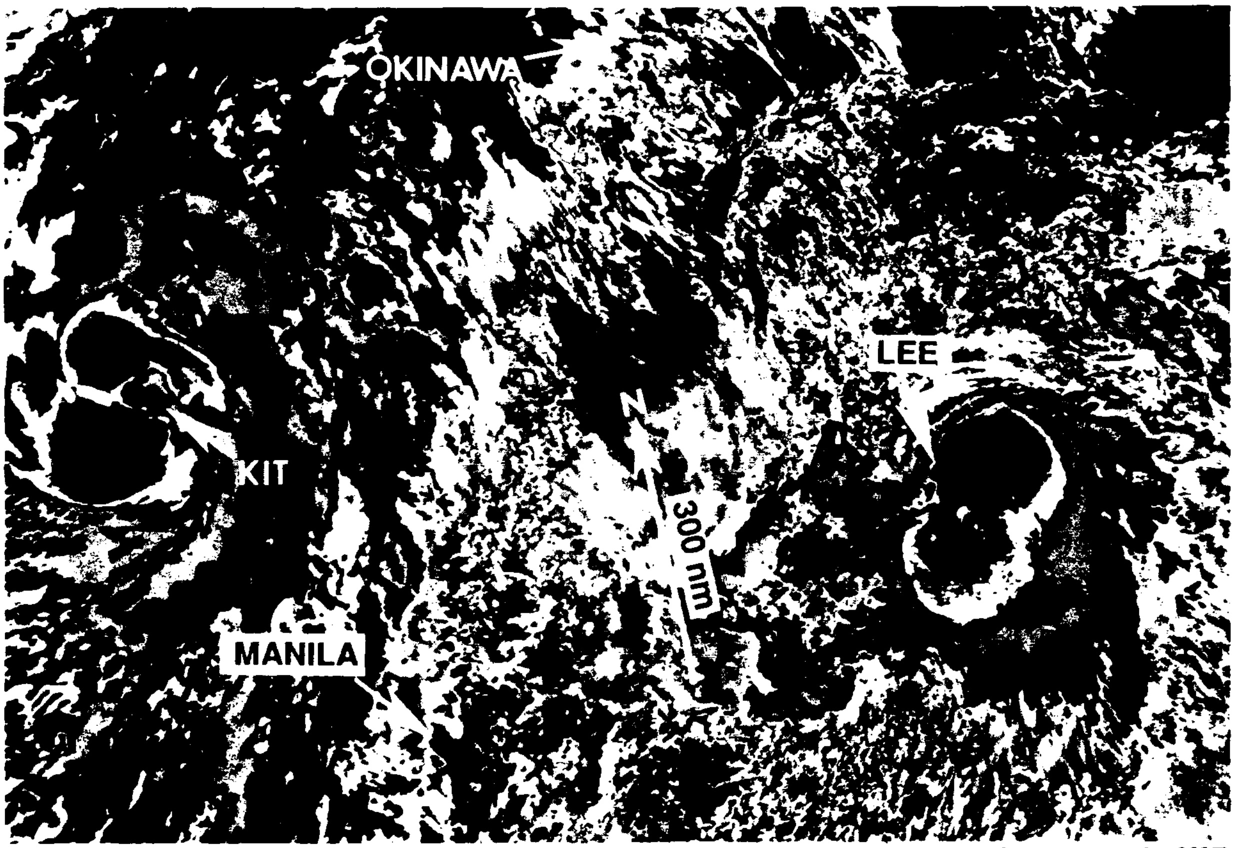
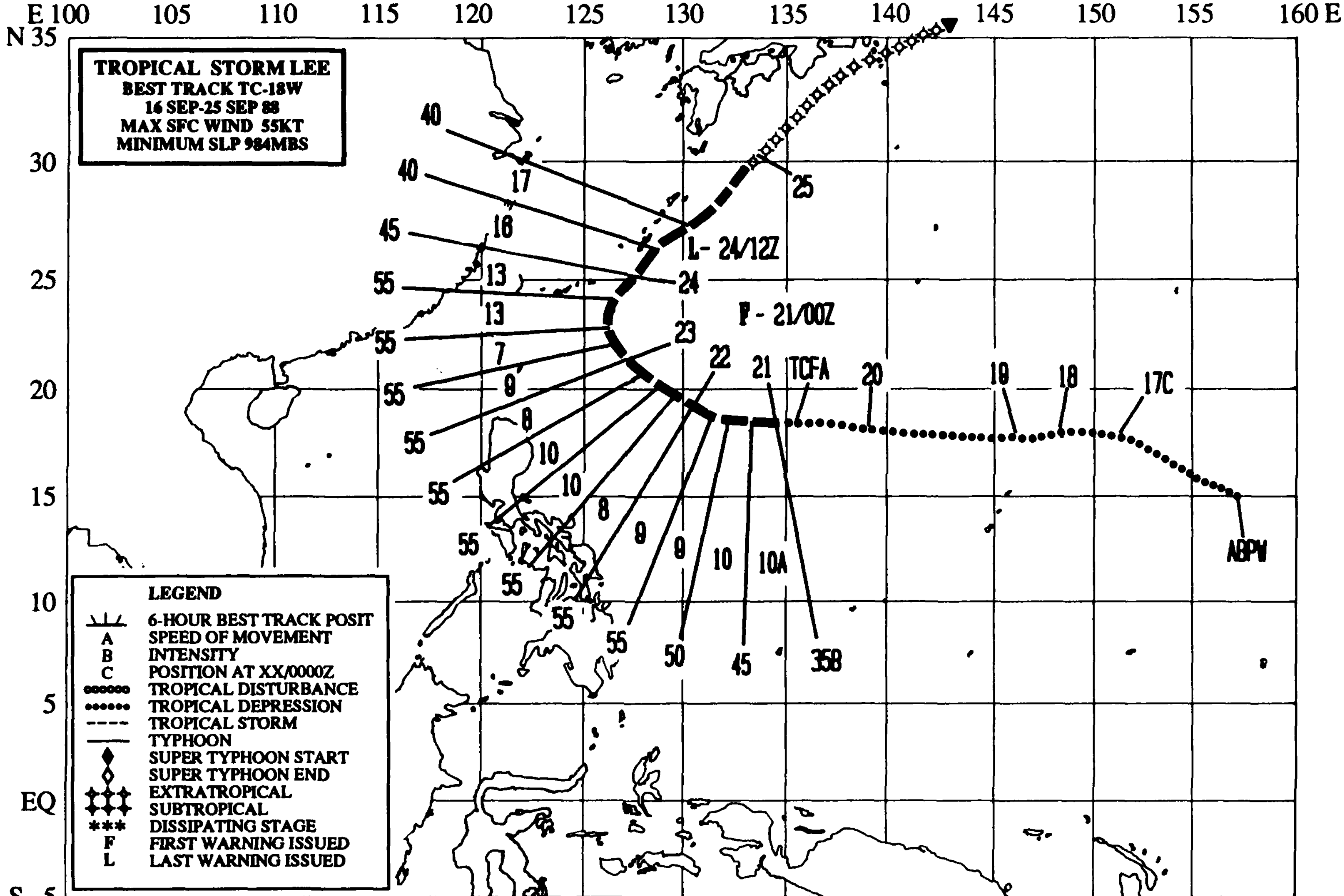


Figure 3-17-2. Kit at peak intensity (to the left) and Tropical Storm Lee (18W) (to the lower right of the picture) (211003Z September DMSP infrared imagery).

Intentionally left blank.


TROPICAL STORM LEE
BEST TRACK TC-18W
16 SEP-25 SEP 88
MAX SFC WIND 55KT
MINIMUM SLP 984MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 24/12Z
F - 21/00Z
TCFA
17C
ABPW
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ
S 5

TROPICAL STORM LEE (18W)

Tropical Storm Lee was the seventh of eight significant tropical cyclones to occur during September. Lee had a formative period of over four days, and was tracked over 1300 nm (2408 km) as an identifiable area of convection before the first warning was issued.

On 16 September Tropical Storms Irma (15W) and Jeff (16W) had just been finalled, Typhoon Hal (14W) was recurving east of Japan and a new area of persistent convection was mentioned on the Significant Tropical Weather Advisory at 160600Z. This persistent convection was tropical upper-tropospheric trough (TUTT) induced (Sadler, 1979) and was superimposed on the broad low-level easterly flow. A steady westward movement was noted for the next four days, during which time there was little change in the poorly organized convection. At 200600Z the disturbance was upgraded to a "fair" suspect area due to improved organization. A Tropical Cyclone Formation Alert followed at 201730Z after the system continued to show improved organization and intensification to 30 kt (15 m/sec) sustained surface winds, based on a satellite analysis estimate. Another estimate of 35 kt (18 m/sec) sustained surface winds followed at 210000Z and prompted the first warning on Tropical Storm Lee (Figure 3-18-1). Lee

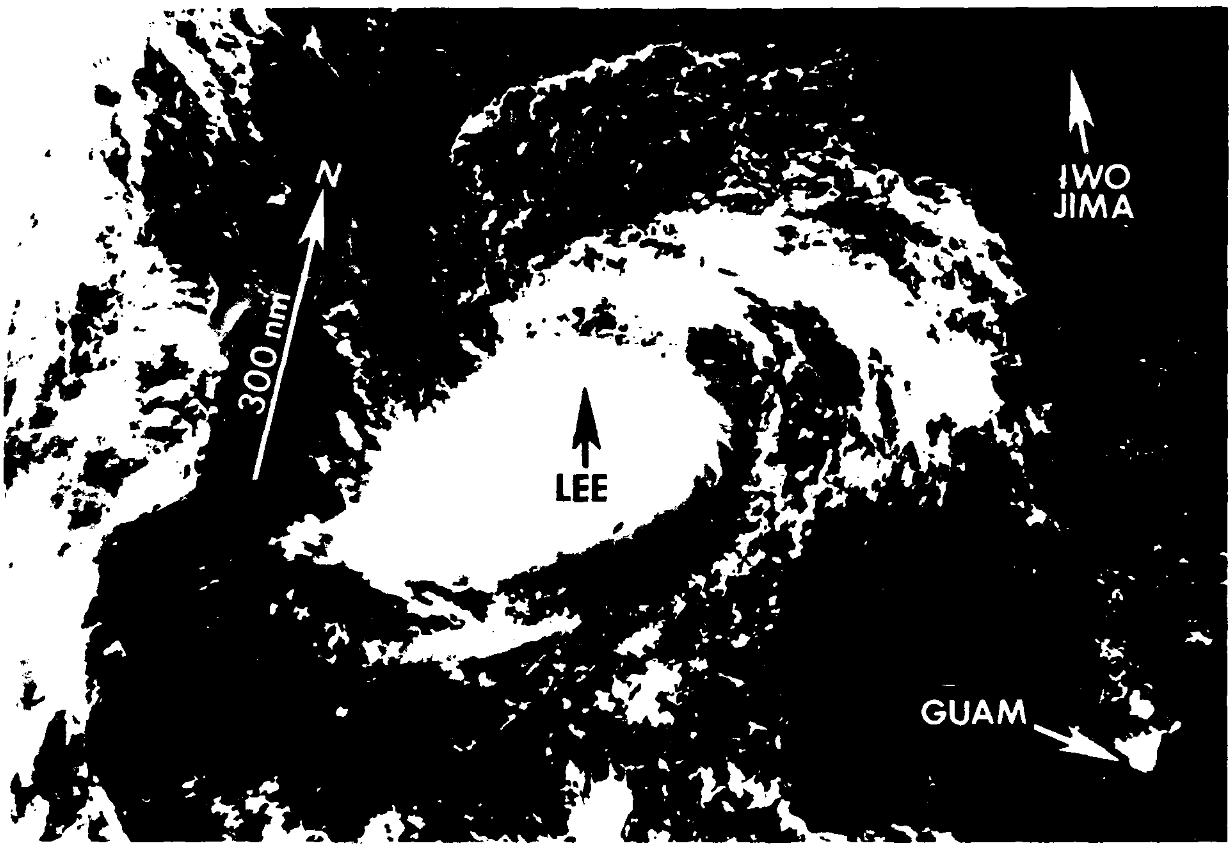


Figure 3-18-1. Tropical Storm Lee just after the first warning. Satellite intensity analysis indicated a T-number of 2.5, corresponding to sustained surface winds of 35 kt (18 m/sec) (210012Z September DMSP visual imagery).

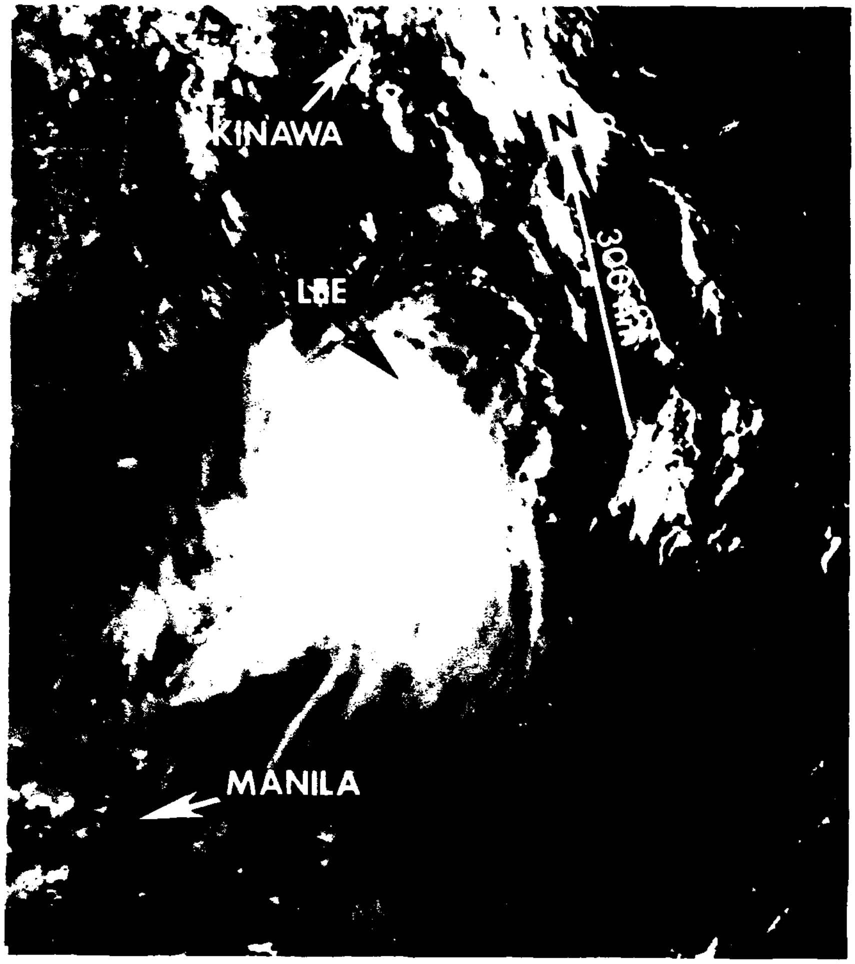


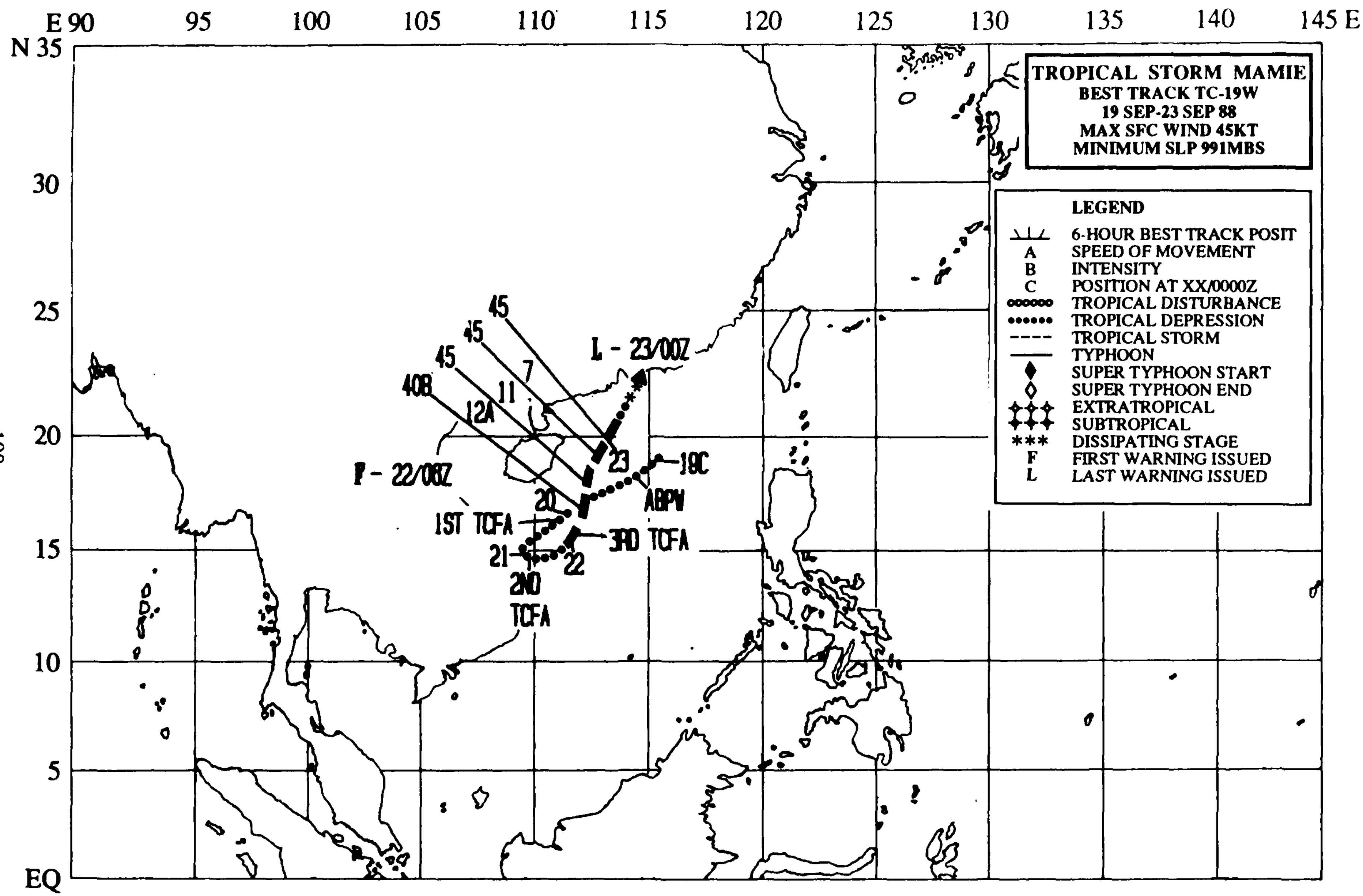
Figure 3-18-2. Shortly before recurvature, Lee shows the effects of increased vertical wind shear. The low-level circulation center is partially exposed to the northeast of the centeral dense overcast (232304Z September DMSP visual imagery).

tracked west-northwestward along the southwestern side of the subtropical ridge for the next 24-hours, and acquired its maximum intensity of 55 kt (28 m/sec) at 211800Z. The forecast was for Lee to continue on its northwestward track around the periphery of the 700 mb subtropical ridge.

Visual satellite imagery (Figure 3-18-2) on 23 September showed a partially exposed low-level circulation center, as Lee encountered increasing vertical wind shear. When night arrived, Lee's poorly defined deep convection provided targets for remote sensing — bright cold tops on the satellite infrared and rain echoes for the radar. Beginning at 231100Z, radar position reports from Ishigaki Jima (WMO 47918) confirmed the movement of the rain echoes to the northwest, which paralleled Kit's (17W) earlier track into southeastern China. However, remarks the following morning on the relocated 240000Z warning summed it up: "Visual satellite pictures indicate Lee has an exposed low-level circulation that has been moving northeastward. Tropical Storm Lee has recurved earlier than expected and should now pass about 55 nm east of Okinawa."

This forecast was accurate and Lee's closest point of approach was 45 nm (83 km) southeast of the island of Okinawa at 240400Z. Lee started to lose its convective organization and showed signs of becoming extratropical at 240600Z. The final warning was issued at 241200Z. Lee became an extratropical low at 242100Z and continued moving rapidly northeastward.

Intentionally left blank.


TROPICAL STORM MAMIE
BEST TRACK TC-19W
19 SEP-23 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 23/00Z
F - 22/06Z
1ST TCFA
2ND TCFA
3RD TCFA
ABPW
19C
20
21
22
23
45
45
7
45
11
40B
12A
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ

TROPICAL STORM MAMIE (19W)

Mamie was the second significant tropical cyclone of 1988 to develop in the South China Sea. It formed in tandem with Tropical Storm Kit (17W) in the monsoon tough and was slow to develop. Typical of monsoon depressions, Mamie proved to be a particularly difficult system to locate and forecast. Large fluctuations in its central convection within the larger synoptic scale trough contributed to this difficulty.

The disturbance that would become Tropical Storm Mamie formed in September, in the monsoon trough, 600 nm (1111 km) west-northwest of Kit (17W). Kit (17W) was at the eastern end of the monsoon trough. Mamie was first mentioned on the Significant Tropical Weather Advisory at 190600Z. During the next 18-hours, the disturbance moved southwestward at 10 kt (19 km/hr), most probably in response to binary interaction with Kit (17W). As Mamie became better organized, its deep convection began the first of several flare-ups. This prompted the first Tropical Cyclone Formation Alert at 200230Z, after satellite intensity analysis indicated 30 kt (15 m/sec) sustained surface winds. The system (Figure 3-19-1) continued southwestward until 210000Z, when it made a sharp turn to the east. The persistent central convection and potential for development required a second Alert at 210030Z.

Later, at 211800Z, the disturbance was headed northeastward along the trough axis — the opposite direction from its initial track, two days earlier. Apparently Mamie's track to the northeast was the result of increased low-level

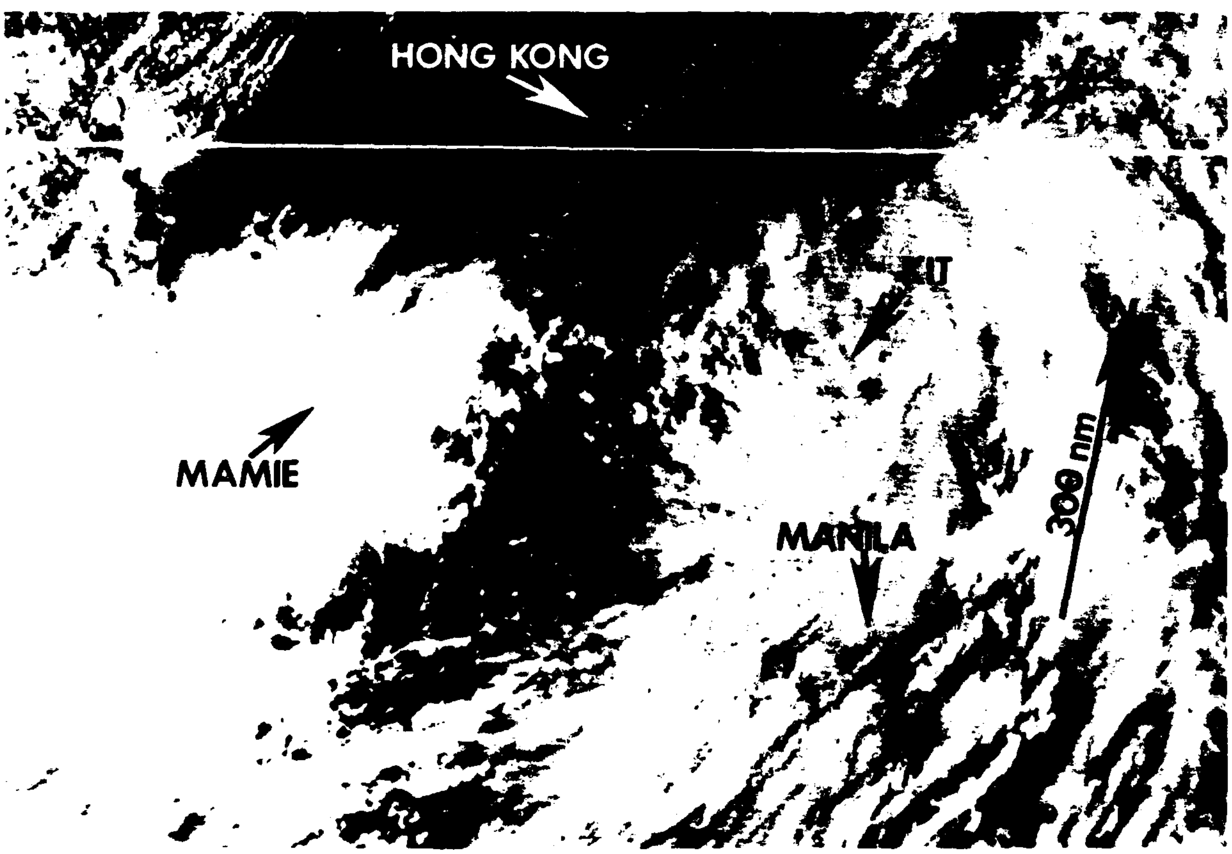
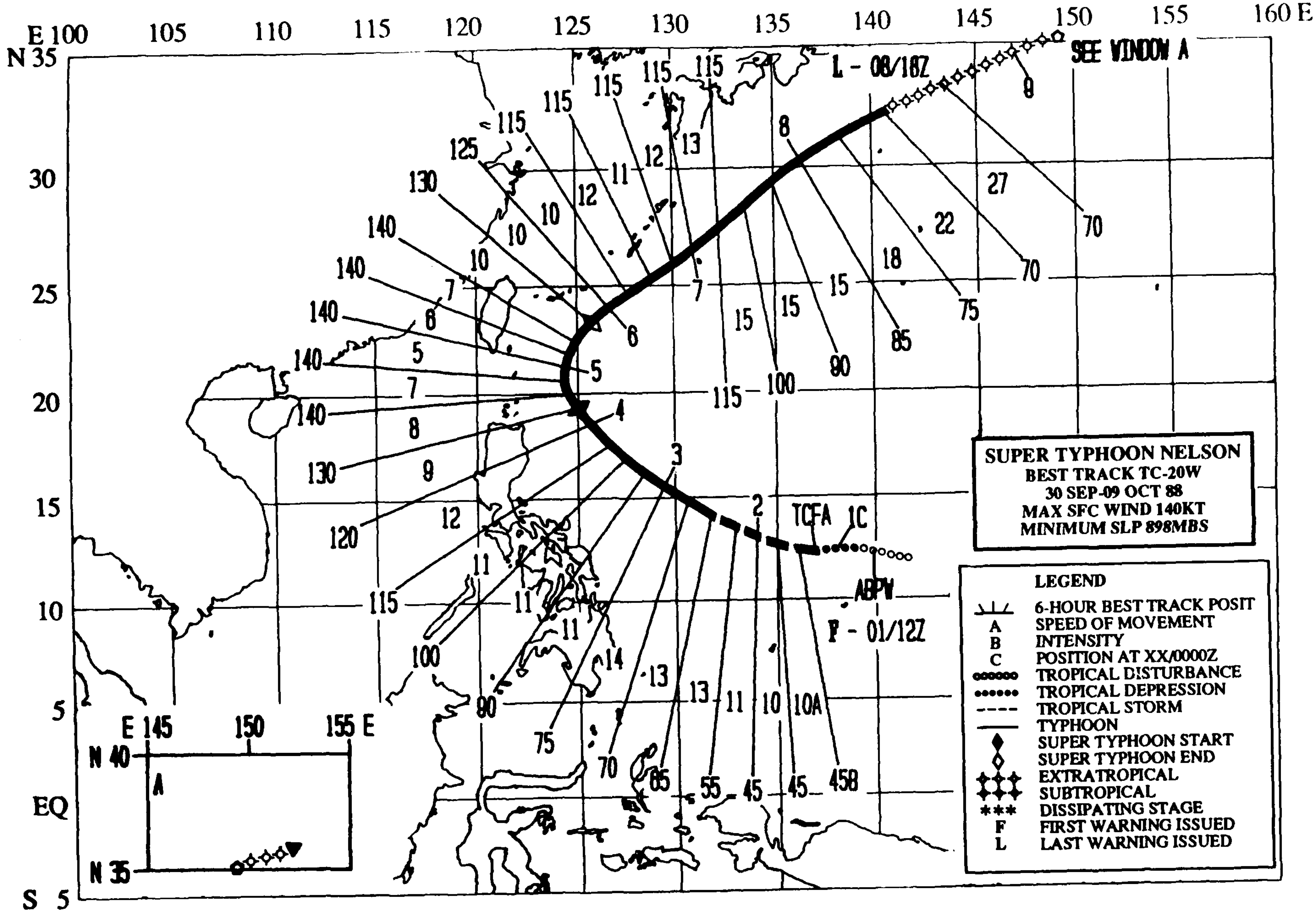


Figure 3-19-1. Mamie, the subject of a Tropical Cyclone Formation Alert, is on the left. To the right of Mamie is Tropical Storm Kit (17W) (200802Z September NOAA visual imagery).

southwesterly inflow into Kit (17W), which was now over water between Luzon and the southeastern coast of China. Mamie maintained its overall convective organization and a third Alert was issued at 220030Z. Based on a ship report of southeasterly surface winds of 40 kt (20 m/sec) and a minimum sea-level pressure of 991 mb, plus a satellite intensity analysis of 35 kt (18 m/sec), the first warning on Tropical Storm Mamie followed at 220600Z. Mamie continued up the monsoon trough axis towards Kit (17W), which had just made landfall in southeastern China. As vertical wind shear increased aloft over Mamie, JTWC issued its final warning at 230000Z. Mamie's remnants, and associated gales, then moved north-northeastward and dissipated on the coast of China northeast of Hong Kong. No reports of damage or loss of life were received.

Intentionally left blank.


SUPER TYPHOON NELSON
BEST TRACK TC-20W
30 SEP-09 OCT 88
MAX SFC WIND 140KT
MINIMUM SLP 898MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
SEE WINDOW A
L - 08/18Z
F - 01/12Z
TCFA
ABPW
A

SUPER TYPHOON NELSON (20W)

Nelson was the first significant tropical cyclone of October and the only super typhoon of 1988. It developed in the Philippine Sea in the monsoon trough. The super typhoon recurved and threatened the Ryukyu Islands and the main Japanese Islands of Kyushu and Honshu.

In late September, after the multiple outbreak of Tropical Storms Kit (17W), Lee (18W) and Mamie (19W), there was a week long lull in tropical cyclone activity. In the meantime polar air pushed southward across the Asian mainland and Japanese Islands. The monsoon trough had returned to its normal climatic location along with the maximum cloud zone. The disturbance that would later become Super Typhoon Nelson was first detected in this maximum cloud zone 200 nm (370 km) southwest of Guam by satellite reconnaissance. The Significant Tropical Weather Advisory, that is normally issued at 0600Z each day, was reissued at 301400Z September to include this area of suspect cloudiness. Nelson developed within the monsoon trough and began steadily organizing (Figure 3-20-1). A noticeable increase in central convection led to the issuance of a

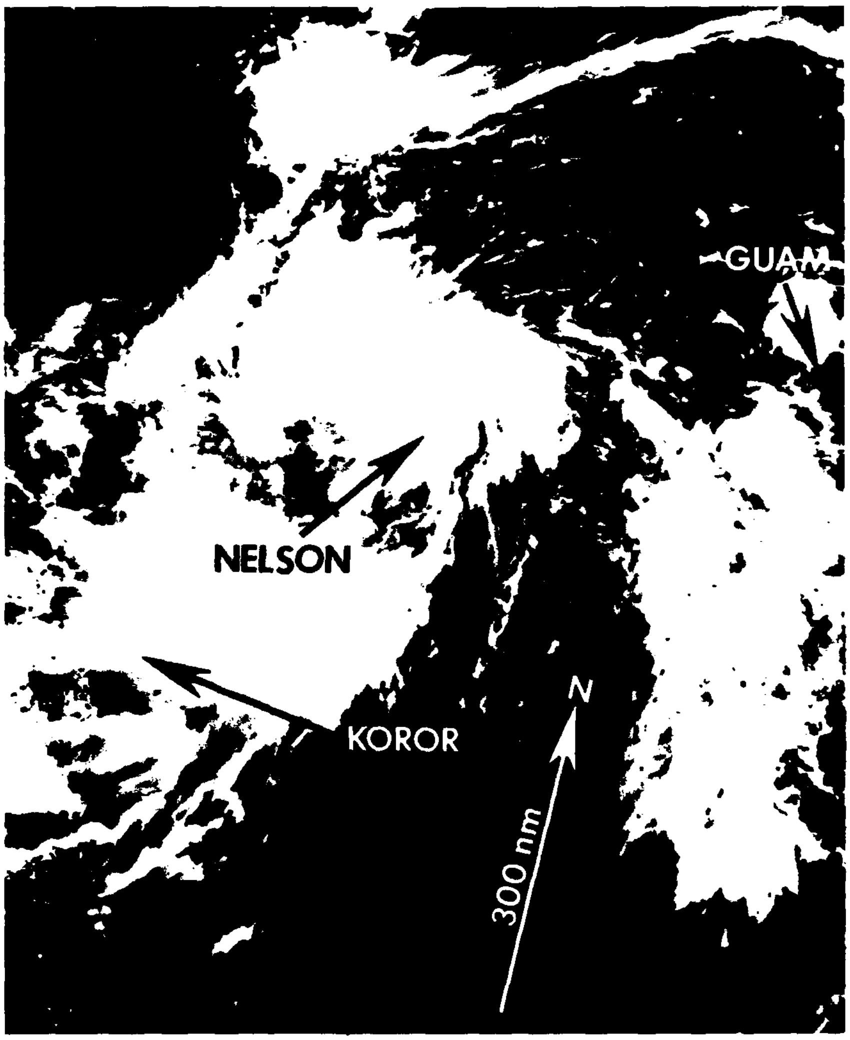


Figure 3-20-1. Nelson as a tropical disturbance (010016Z October DMSP visual imagery).

Tropical Cyclone Formation Alert at 0900Z on 1 October. The first warning followed at 011200Z, based on a satellite intensity estimate of 45 kt (23 m/sec) sustained surface winds. (Post analysis indicates the disturbance, most probably, achieved tropical storm intensity earlier at 010600Z.) Nelson initially moved westward towards the Philippine Islands, and then west-northwestward as it tracked along the periphery of the subtropical ridge.

Only 24 hours after the initial warning was issued, a satellite intensity estimate of 65 kt (33 m/sec) winds resulted in an upgrade to typhoon status at 021200Z. At 022100Z, a 15 nm (28 km) diameter eye first became visible on satellite imagery. (The eye persisted until 7 October.) Nelson continued to rapidly intensify and reached super typhoon intensity at 040600Z (Figure 3-20-2). The normal rate of intensification (Dvorak, 1984) is one T-number per day. From 020000Z to 041200Z, Nelson developed more rapidly than normal (Figure 3-20-3). Conversion (Atkinson and Holliday, 1977) of intensity to minimum sea-level pressure indicates a fall from 991 to 898 mb — 93 mb in 60-hours — and sustained rapid intensification (Holliday and Thompson, 1979)(Figure 3-20-4). On 4 October, Nelson slowed and tracked through an area where, according to climatology (Annual Typhoon Report, 1970), a large number of tropical cyclones reach super typhoon intensity (Figure 3-20-5). The typhoon's intensity peaked at 140 kt (72 m/sec) at 041200Z.

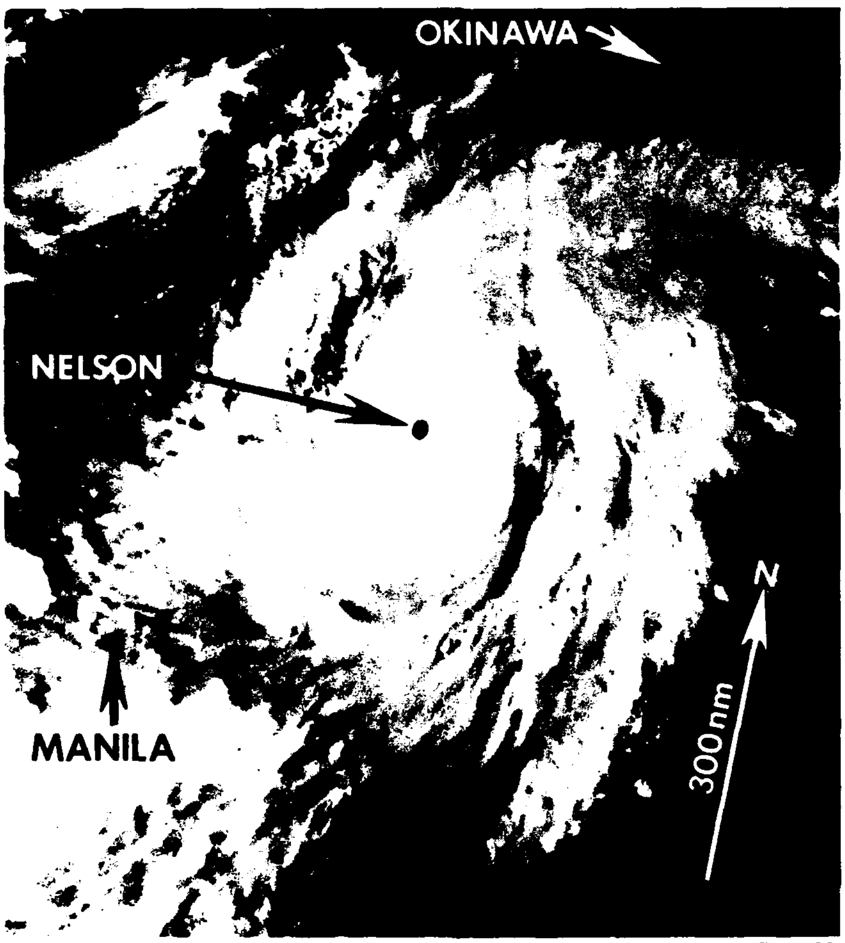


Figure 3-20-2. Super Typhoon Nelson near peak intensity displays a well defined 20 nm (37 km) diameter eye (040709Z October NOAA visual imagery).

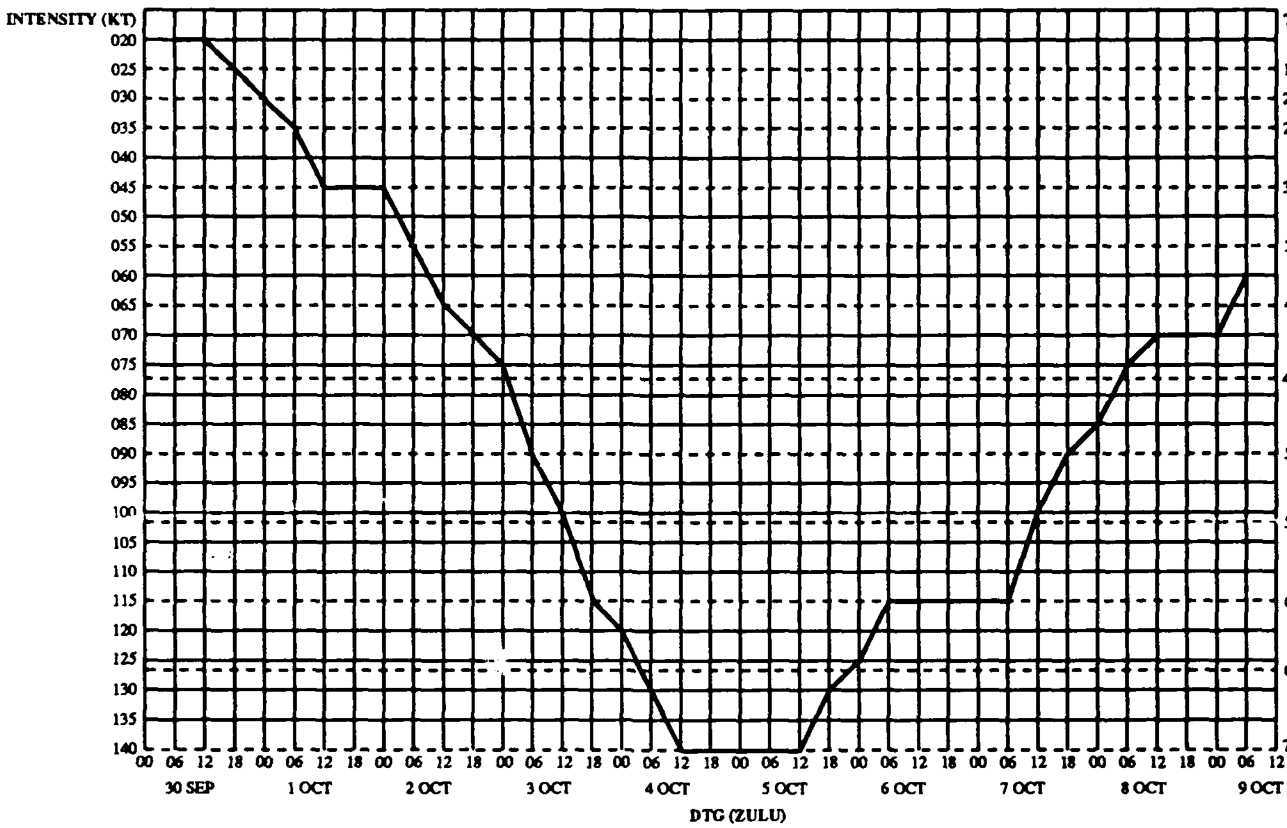


Figure 3-20-3. Analysis of intensity with time shows Super Typhoon Nelson's rapid intensification from 020000Z to 041200Z October. Note the peak intensity of 140 kt (72 m/sec) persisted from 041200Z to 051200Z October.

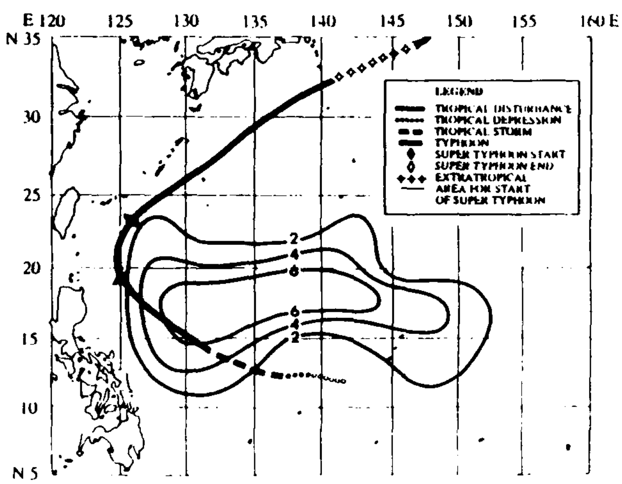


Figure 3-20-4. Nelson's final best track is superimposed upon the areas where tropical cyclones rapidly intensified during summer and early fall (20 June - 16 October) for the years 1956 to 1976 (Holliday and Thompson, 1979).

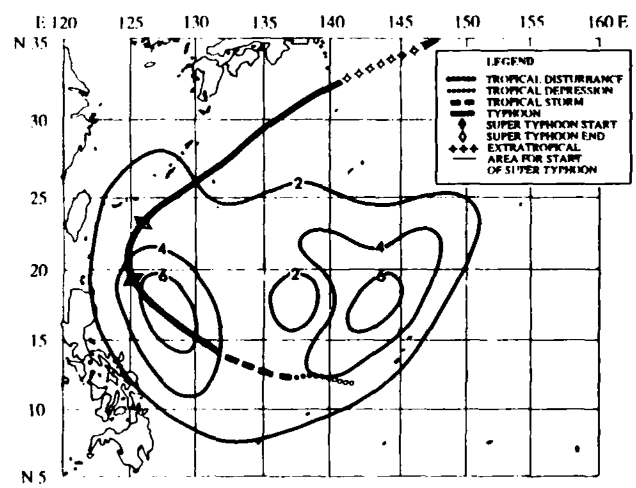


Figure 3-20-5. Nelson's final best track superimposed upon climatic areas of super typhoon occurrence. Areas of first super typhoon intensity include number of occurrances from the period 1959 to 1970 (Annual Typhoon Report, 1970).

Packing the most intense winds of any tropical cyclone for the year, Nelson rounded the western end of the subtropical ridge at a speed of 6 kt (11 km/hr), and slowly accelerated northeastward. In addition to satellite reconnaissance, a total of 177 radar position reports greatly aided the accurate tracking of the typhoon's recurvature and subsequent acceleration. Moving along the edge of the modifying polar air, Nelson weakened and was downgraded to typhoon intensity at 060000Z. The tropical cyclone passed 85 nm (157 km) southeast of the island of Okinawa at 060930Z (Figures 3-20-6 and 3-20-7). The maximum

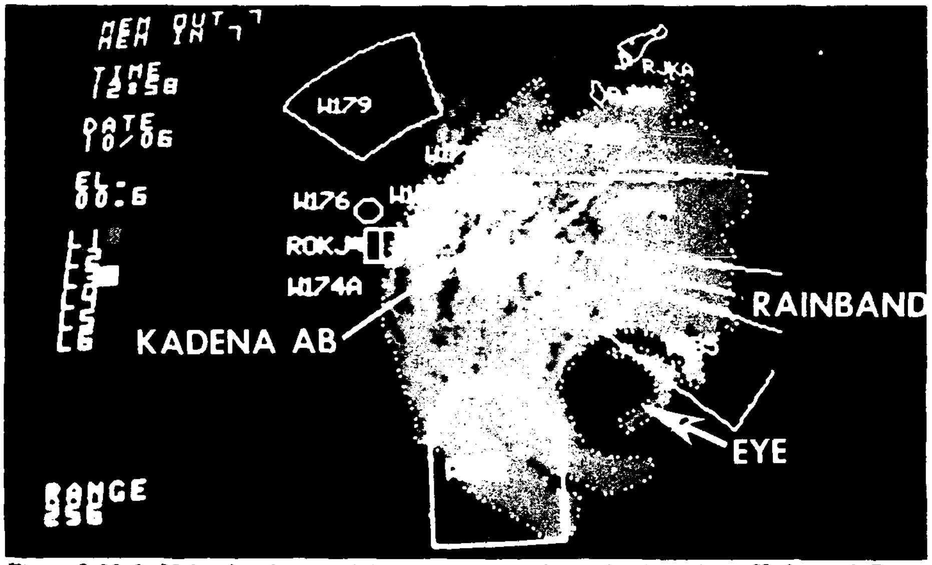


Figure 3-20-6. Nelson's primary rainband and eye as viewed by the radar at Kadena Air Base, Okinawa at 061258Z. Dots have been added to enhance the subtle edge of the rain echoes (photograph courtesy of Detachment 8, 20th Weather Squadron).

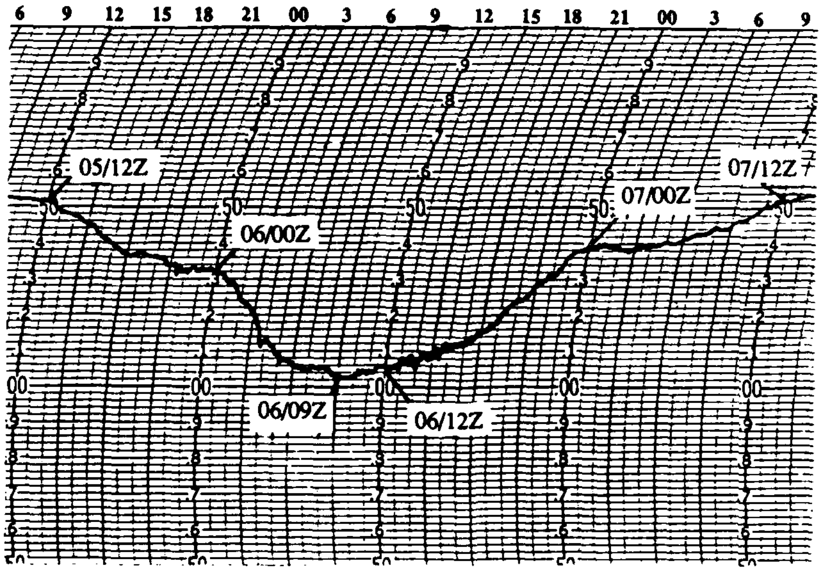


Figure 3-20-7. Microbarograph trace from Kadena Air Base, Okinawa. The time of the lowest minimum sea-level pressure of 29.02 inches Hg coincides with Nelson's closest approach to the island (barograph trace courtesy of Detachment 8, 20th Weather Squadron).

sustained winds reported by Detachment 8, 20th Weather Squadron at Kadena Air Base on Okinawa were 38 kt (20 m/sec), with a peak gust of 59 kt (30 m/sec). Close by, maximum sustained winds of 40 kt (21 m/sec), with a peak gust of 64 kt (33 m/sec) were reported by the Marine Corps Air Station at Futenma. The rainfall totals recorded on Okinawa ranged from 7.30 inches (18.54 cm) at Futenma to 8.35 inches (21.21 cm) at Kadena Air Base.

Nelson continued to weaken, move northeastward and accelerate (Figure 3-20-8). As it lost its persistent central convection, the typhoon transitioned to an extratropical system 190 nm (352 km) southeast of Tokyo, Japan at 081500Z. By this time it was moving at a speed of 28 kt (52 km/hr). Extratropical Nelson retained winds of typhoon intensity and moved rapidly northeastward. The final warning was issued at 081800Z. The remnants of Nelson were identifiable on satellite imagery for the next two days. No reports of significant damage were received.

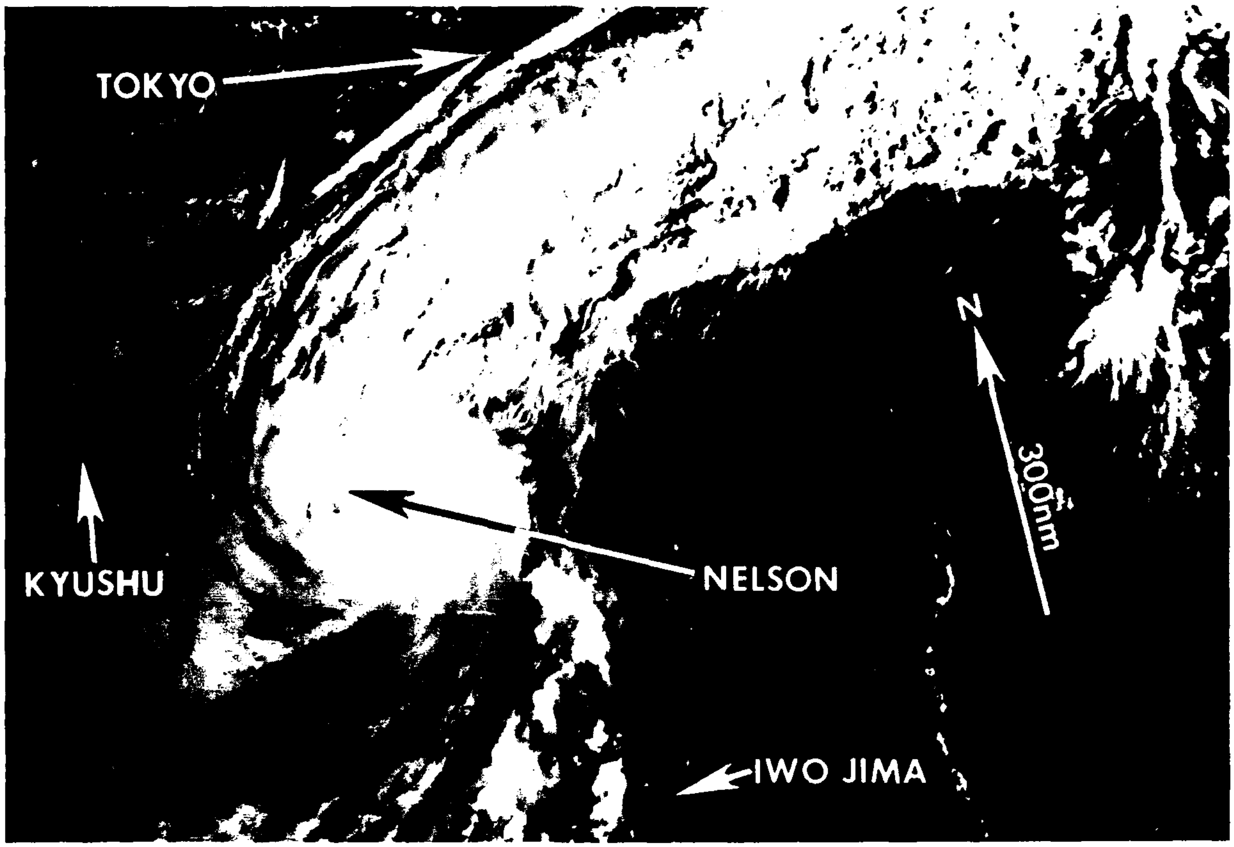
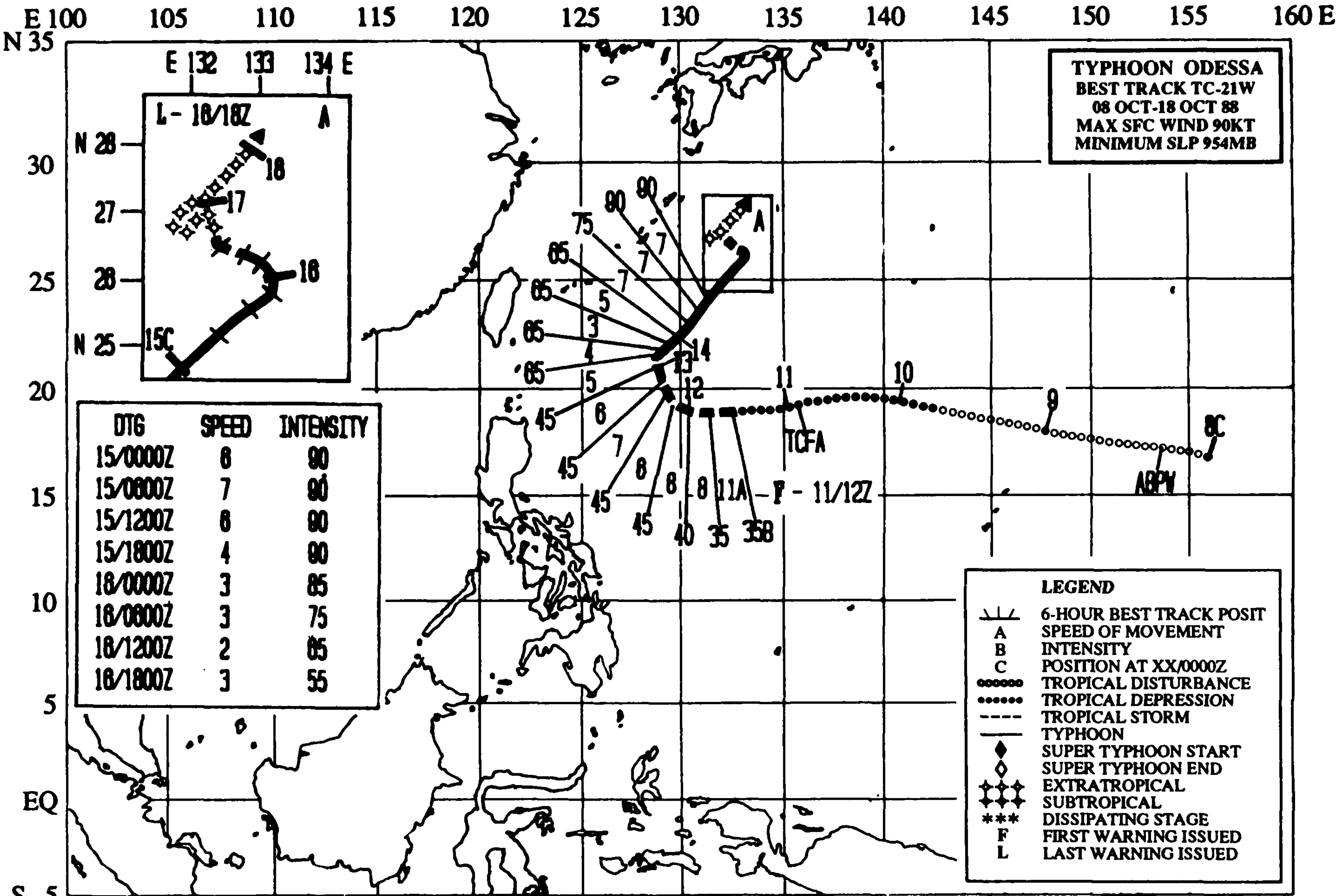


Figure 3-20-8. Nelson during its weakening stage (072235Z October NOAA visual imagery).


TYPHOON ODESSA
BEST TRACK TC-21W
08 OCT-18 OCT 88
MAX SFC WIND 90KT
MINIMUM SLP 954MB
DTG SPEED INTENSITY
15/0000Z 8 90
15/0600Z 7 90
15/1200Z 8 90
15/1800Z 4 90
16/0000Z 3 85
16/0600Z 3 75
16/1200Z 2 65
16/1800Z 3 55
L - 16/18Z
A
F - 11/12Z
TCFA
ABPW
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON ODESSA (21W)

Odessa was the second of four significant tropical cyclones to occur during October. Slow to develop, it was tracked for three and a half days by satellite before the first warning was issued. After recurvature, Odessa rapidly intensified into a midget typhoon, despite interaction with a frontal system.

On 8 October, as Super Typhoon Nelson (20W) was weakening and accelerating to the northeast in higher latitudes, Odessa began as an area of convection superimposed on broad low-level easterly tradewinds 460 nm (852 km) south-southeast of Minami Tori-Shima. The persistence of this convective area was first mentioned on the Significant Tropical Weather Advisory at 080600Z. After two days of faster than normal — 17 to 18 kt (32 to 33 km/hr) — movement to the west-northwest, surface winds in the area increased to 30 kt (15 m/sec). At 102100Z, the Significant Tropical Weather Advisory was reissued to address this increase (Figure 3-21-1) and a Tropical Cyclone Formation Alert followed at 102300Z. A satellite intensity estimate of 35 kt (18 m/sec) prompted the first warning at 111200Z.

At 121800Z, Odessa was moving north-northwestward toward the cooler, drier polar air that was spilling off the Asian mainland. As interaction with this air mass commenced, the tropical cyclone began tracking to the northeast and intensifying. Satellite intensity analysis at 131106Z indicated sustained surface winds of 65 kt (33 m/sec) and Odessa was upgraded to a typhoon at 131200Z. Initially, the interaction with the cold front was expected to weaken the tropical cyclone; instead Odessa intensified into

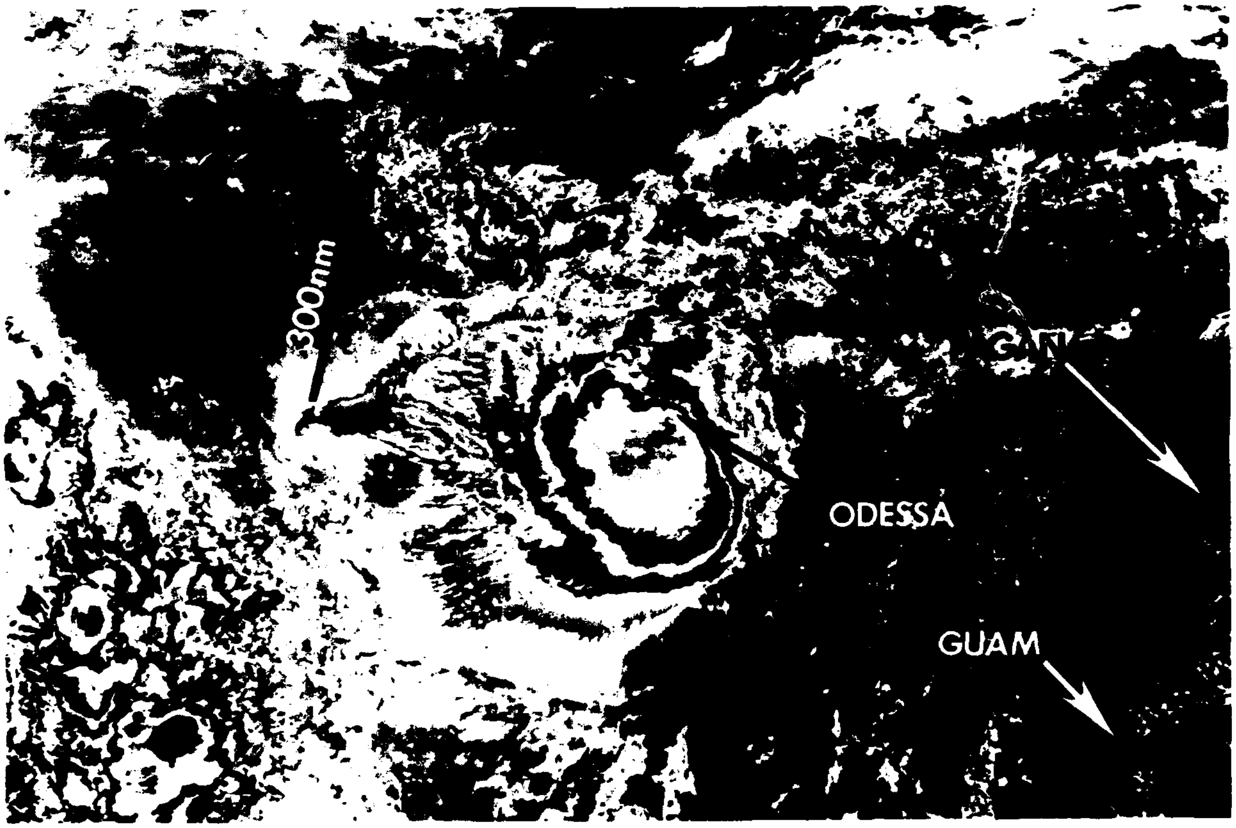


Figure 3-21-1. Odessa as a tropical disturbance (110021Z October DMSP infrared imagery).

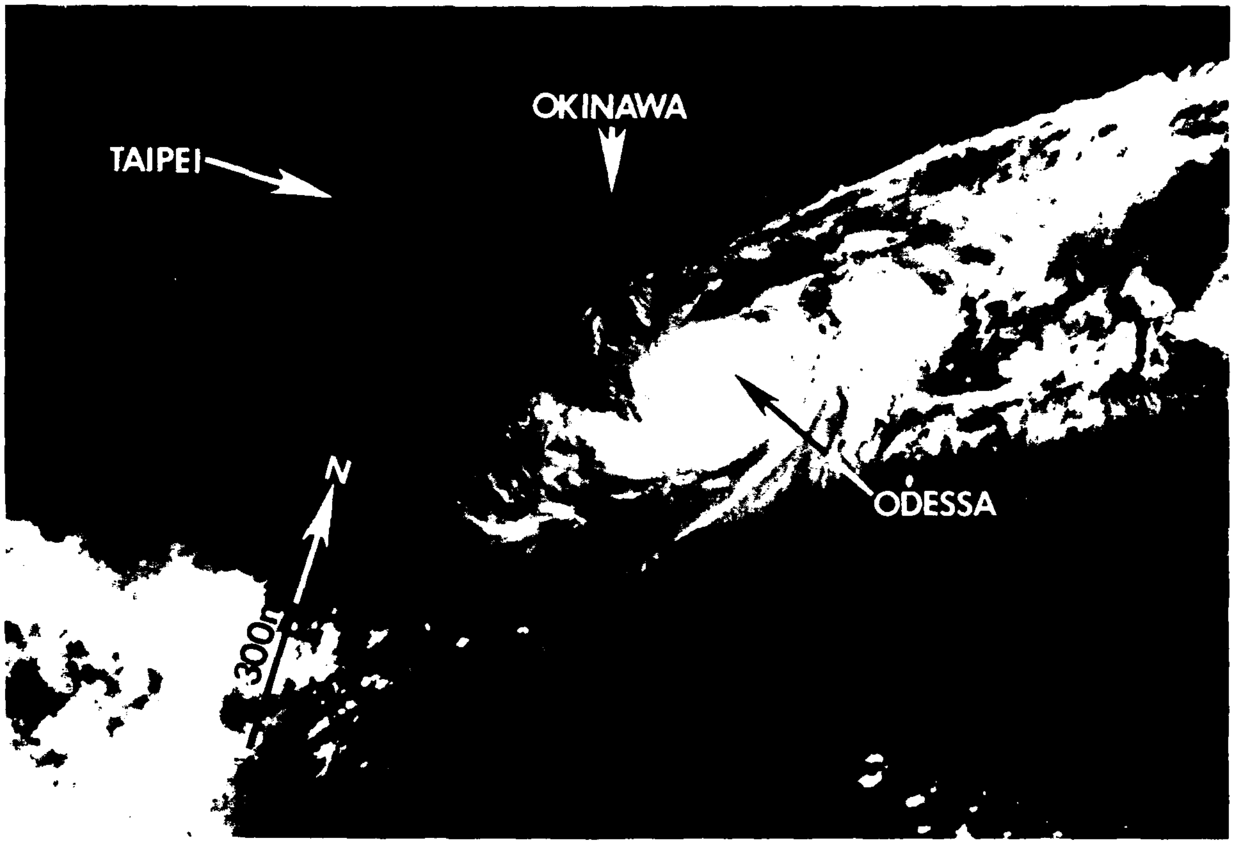


Figure 3-21-2. Typhoon Odessa displays a small eye before attaining its peak intensity (141044Z October NOAA visual imagery).

a midget typhoon. At 141200Z, the intensity peaked at 90 kt (46 m/sec) (Figure 3-21-2).

Loss of organization and deep convection started to be evident at 151200Z. With extratropical transition underway and the low-level circulation exposed, the final warning was issued at 161800Z. The extratropical circulation (Figure 3-21-3) made a counter-clockwise loop on 17 October before moving off to the northeast along the frontal zone.

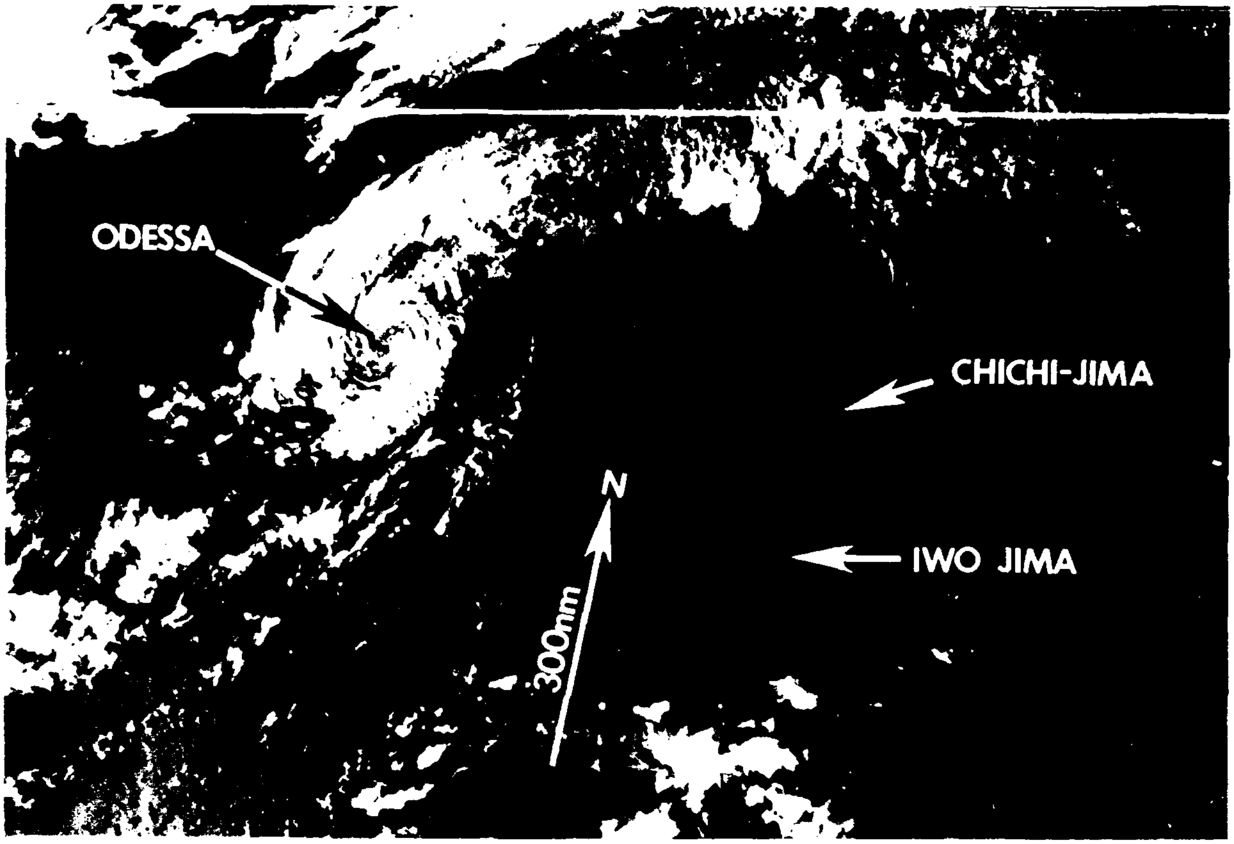
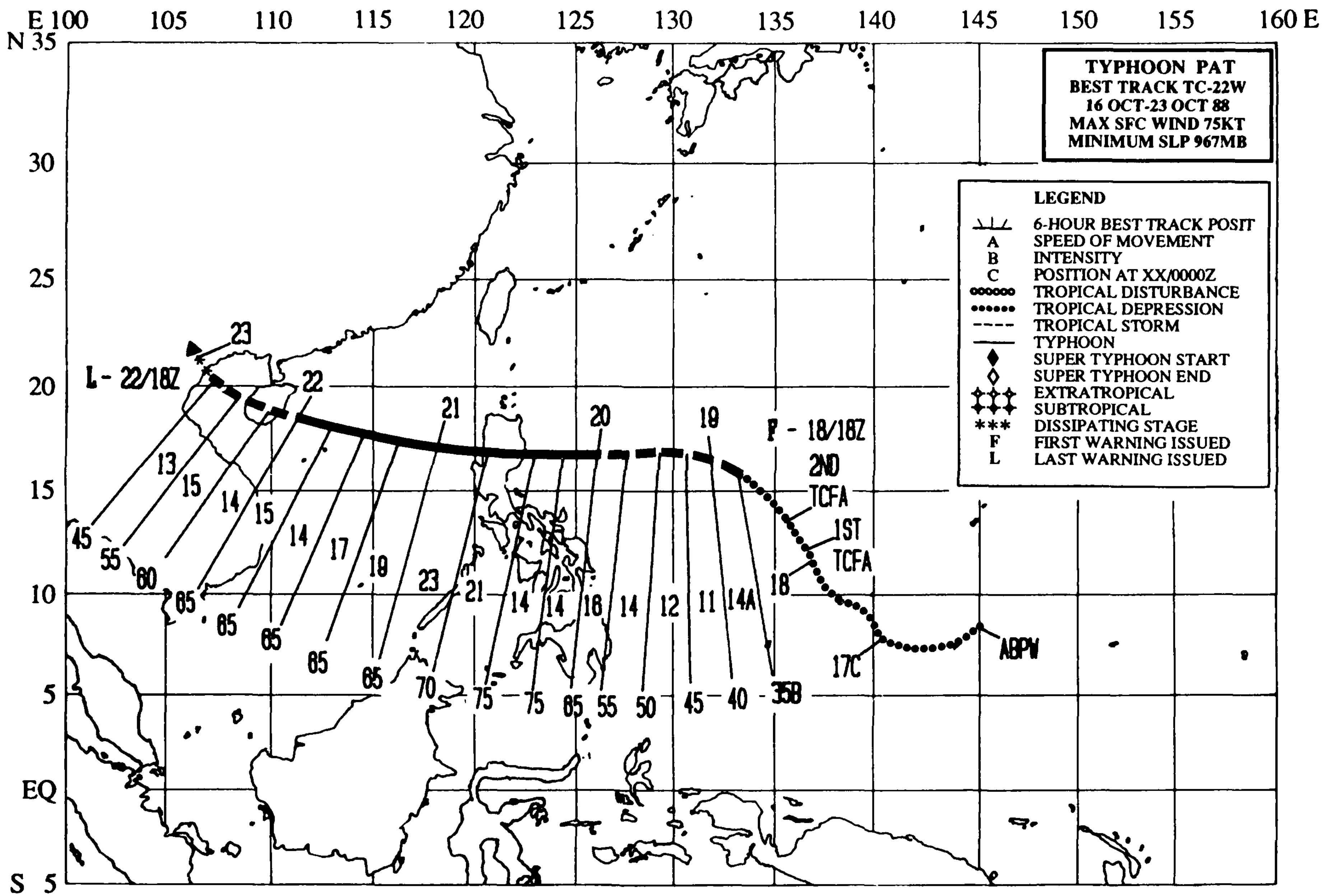


Figure 3-21-3. Odessa's well organized low-level circulation persists (170627Z October NOAA visual imagery).


TYPHOON PAT
BEST TRACK TC-22W
16 OCT-23 OCT 88
MAX SFC WIND 75KT
MINIMUM SLP 967MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
F - 18/18Z
L - 22/18Z
2ND TCFA
1ST TCFA
ABPW
17C

TYPHOON PAT (22W)

Pat was the third of four typhoons to develop during October. Unlike most of the western North Pacific tropical cyclones in 1988 that preceded, it formed equatorward of 10 degrees North latitude.

The tropical cyclone was first detected on satellite imagery and the Significant Tropical Weather Advisory was reissued at 160630Z to include the low-level cyclonic circulation, which was located 300 nm (556 km) south of Guam. Initially, synoptic and satellite data comparison indicated the maximum convection was in a convergent zone south of the low-level circulation. From 16 to 18 October, Pat slowly developed over the warm Philippine Sea and moved through an area of relatively low vertical wind shear. By 18 October the convection had organized and the first Tropical Cyclone Formation Alert was issued at 180300Z. Surface synoptic data indicated a minimum sea-level pressure (MSLP) of about 1002 mb and winds of 25 to 30 kt (13 to 15 m/sec). Satellite imagery continued to show an uneven distribution of deep convection with significantly more convection in the system's eastern semicircle. Pat's slow development required a second Alert at 181530Z. Improving upper-level outflow and increasing central convection prompted the first warning at 181800Z.

Then Pat (Figure 3-22-1) assumed a more westerward course along the edge of the

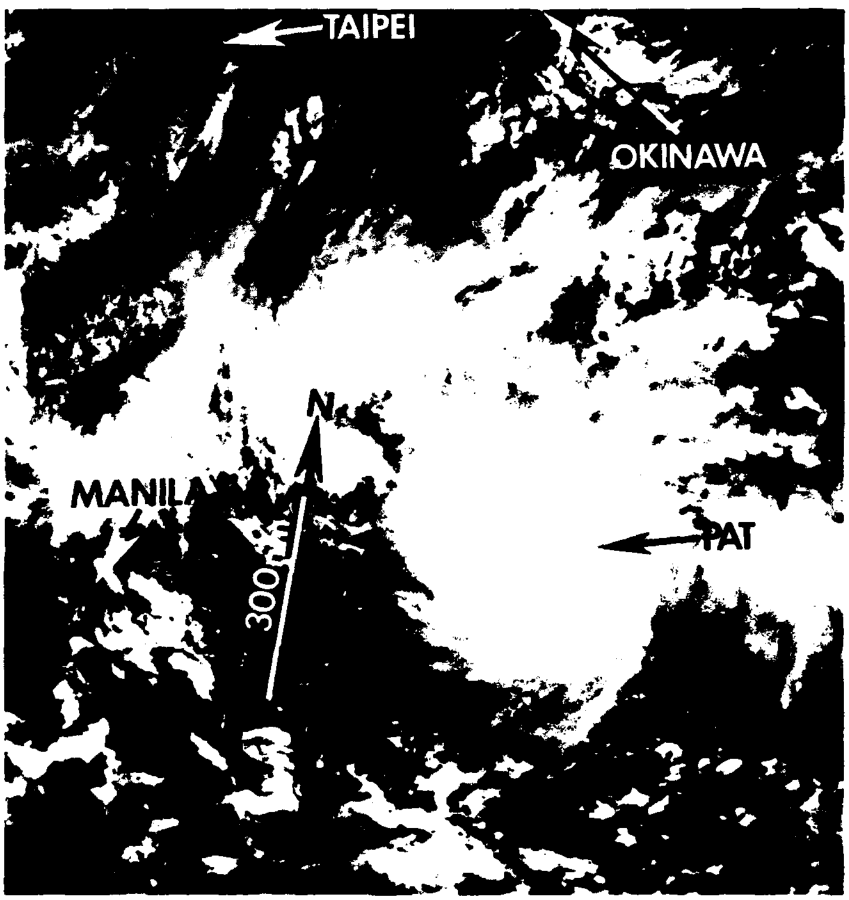


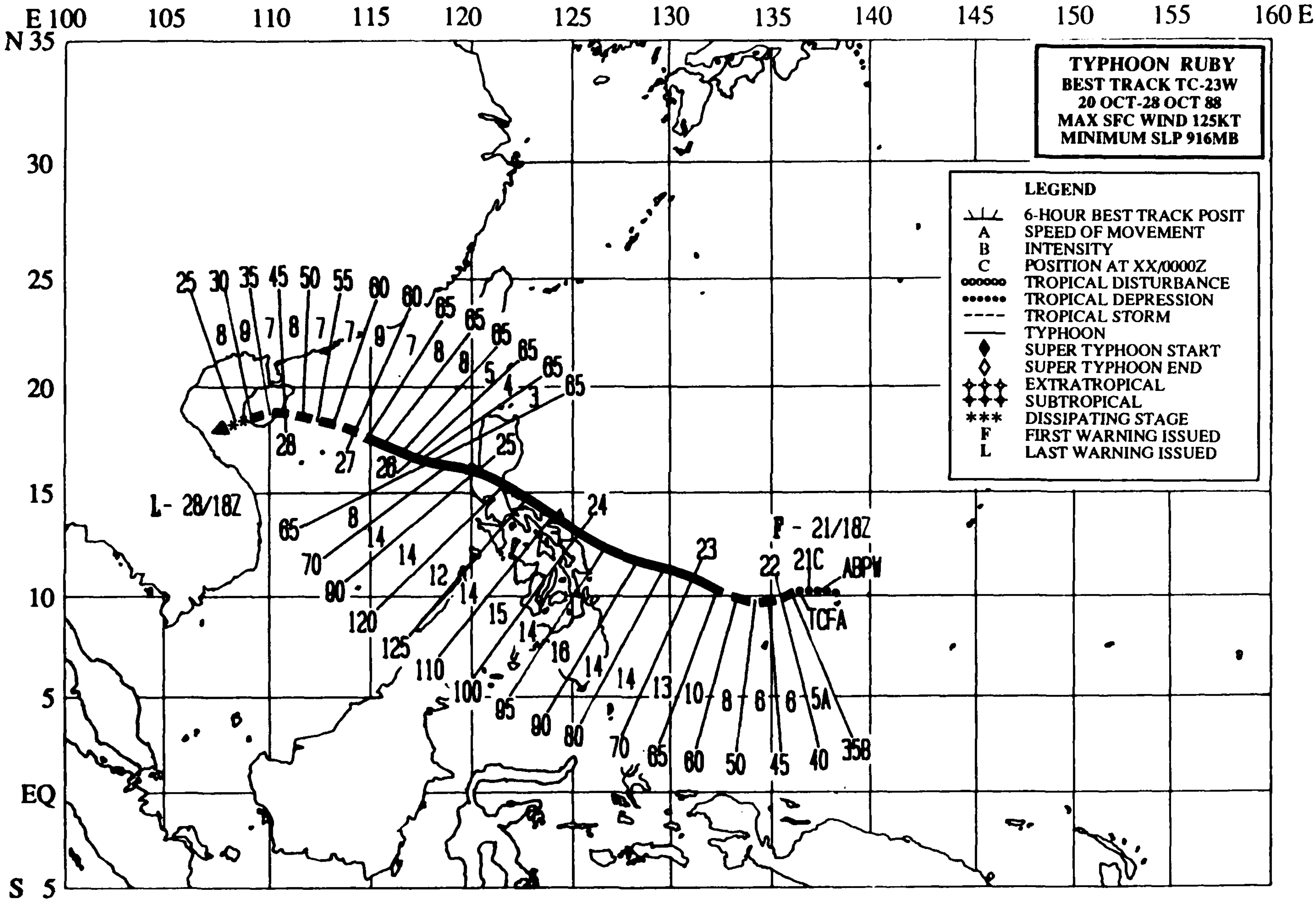
Figure 3-22-1. Pat crossing the Philippine Sea (190514Z October NOAA visual imagery).

modifying polar high to the north. The tropical cyclone's convection and organization increased again, which required an upgrade to typhoon intensity at 200000Z. Shortly before making landfall on the island of Luzon, Pat reached its peak intensity of 75 kt (39 m/sec). Maintaining typhoon intensity as it crossed central Luzon, the system (Figure 3-22-2) passed 75 nm (139 km) north of Clark Air Base at 201800Z . The base, due to the sheltering effect of the nearby mountain ranges, only recorded peak gusts of 21 kt (11 m/sec).

After entering the South China Sea, Pat (Figure 3-22-3) pressed on to the west-northwest and sustained minimal typhoon intensity. It crossed the South China Sea and was downgraded to a tropical storm, as interaction with Hainan Dao occurred. Once across the island, the weakening system moved into the Gulf of Tonkin and entered northern Vietnam. It passed 30 nm (56 km) northeast of Hanoi and dissipated inland.

Figure 3-22-2. Typhoon Pat entering the South China Sea (202152Z October DMSP infrared imagery).

Figure 3-22-3. Typhoon Pat approaches Hainan Dao (220011Z October NOAA visual imagery).


TYPHOON RUBY
BEST TRACK TC-23W
20 OCT-28 OCT 88
MAX SFC WIND 125KT
MINIMUM SLP 916MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
F - 21/18Z
L- 28/18Z
ABPW
TCFA
E 100
105
110
115
120
125
130
135
140
145
150
155
160 E
N 35
30
25
20
15
10
5
EQ
S 5

TYPHOON RUBY (23W)

The last of four typhoons to develop in the western North Pacific during October, Ruby became the fifth tropical cyclone to hit the Philippine Islands in 1988.

On 20 October, as Typhoon Pat (22W) approached the Philippine Islands, Ruby formed to the east in the Philippine Sea. The Significant Tropical Weather Advisory was reissued at 201800Z to include this new disturbance. Increased central convection and organization warranted a Tropical Cyclone Formation Alert at 210430Z and the first warning at 211200Z.

Ruby assumed the track of a "straight runner" and continued to intensify. At 240600Z, as it neared land, Ruby developed a 15 nm (28 km) diameter eye and reached its peak intensity of 125 kt (64 m/sec) at 241200Z. The eye persisted for twelve hours before Ruby tracked into the mountainous terrain of central Luzon (Figure 3-23-1).

Like most tropical cyclones that track over the Philippine Islands, Ruby weakened significantly as it moved across Luzon; however, it was near super typhoon intensity shortly before it made landfall. The result was widespread damage and loss of life. More than three hundred people were killed, including over 150 who drowned when the ferry DONA MARILYN capsized at sea 300 nm (556 km) southeast of Manila, and over 470,000 people

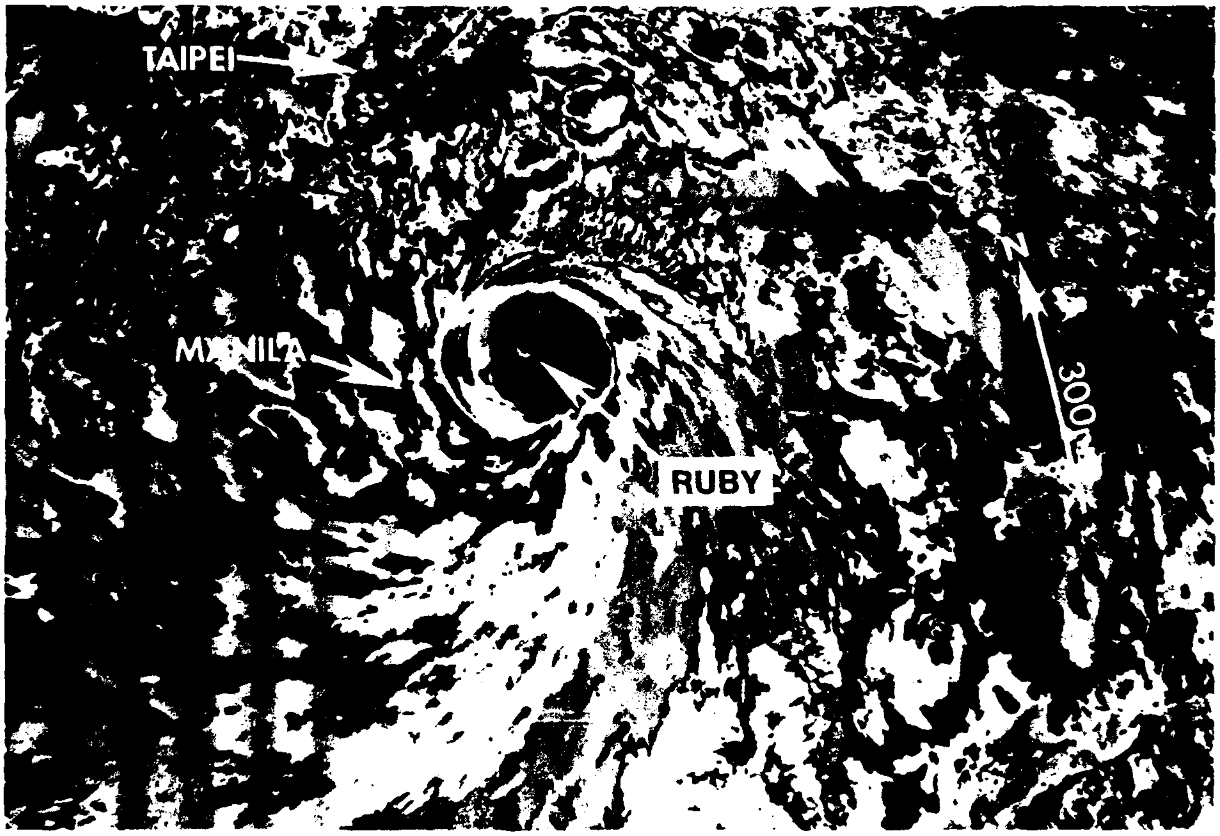


Figure 3-23-1. Ruby, shortly before reaching its peak intensity and making landfall over central Luzon (241000Z October DMSP infrared imagery).

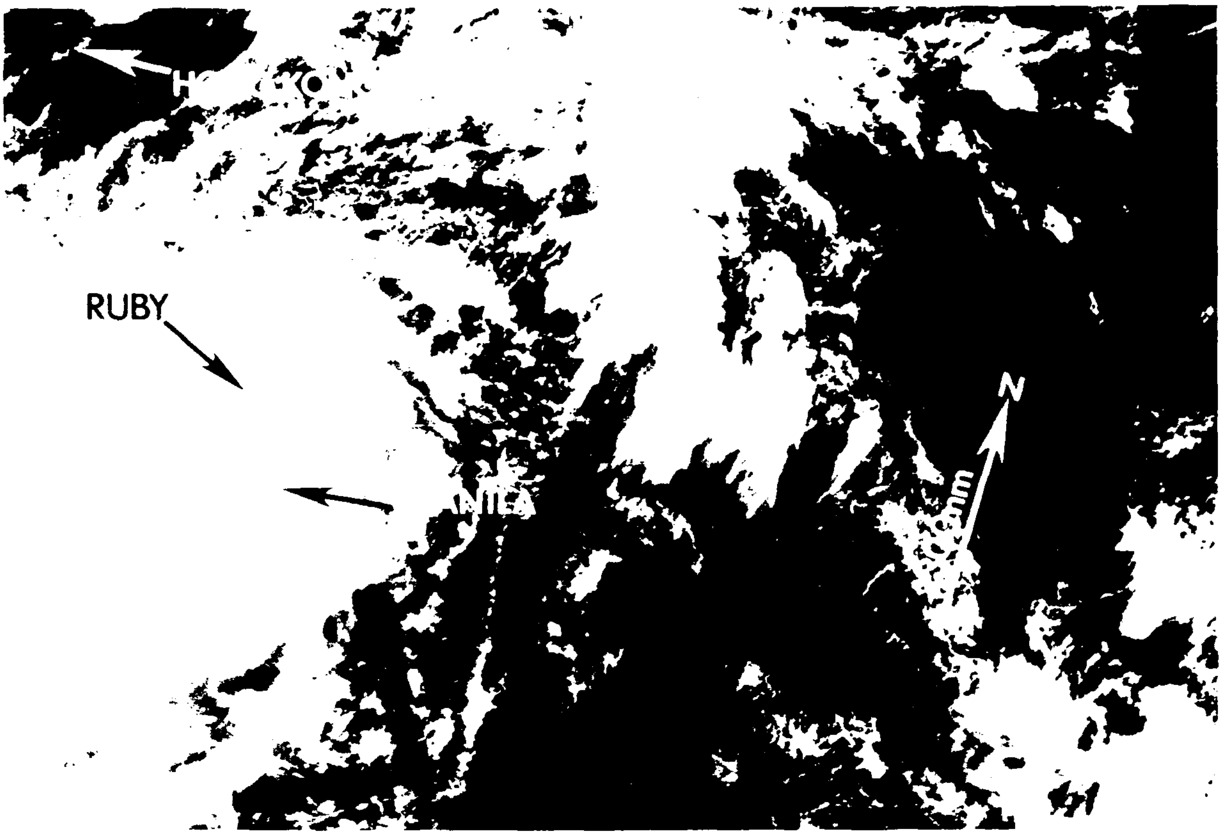


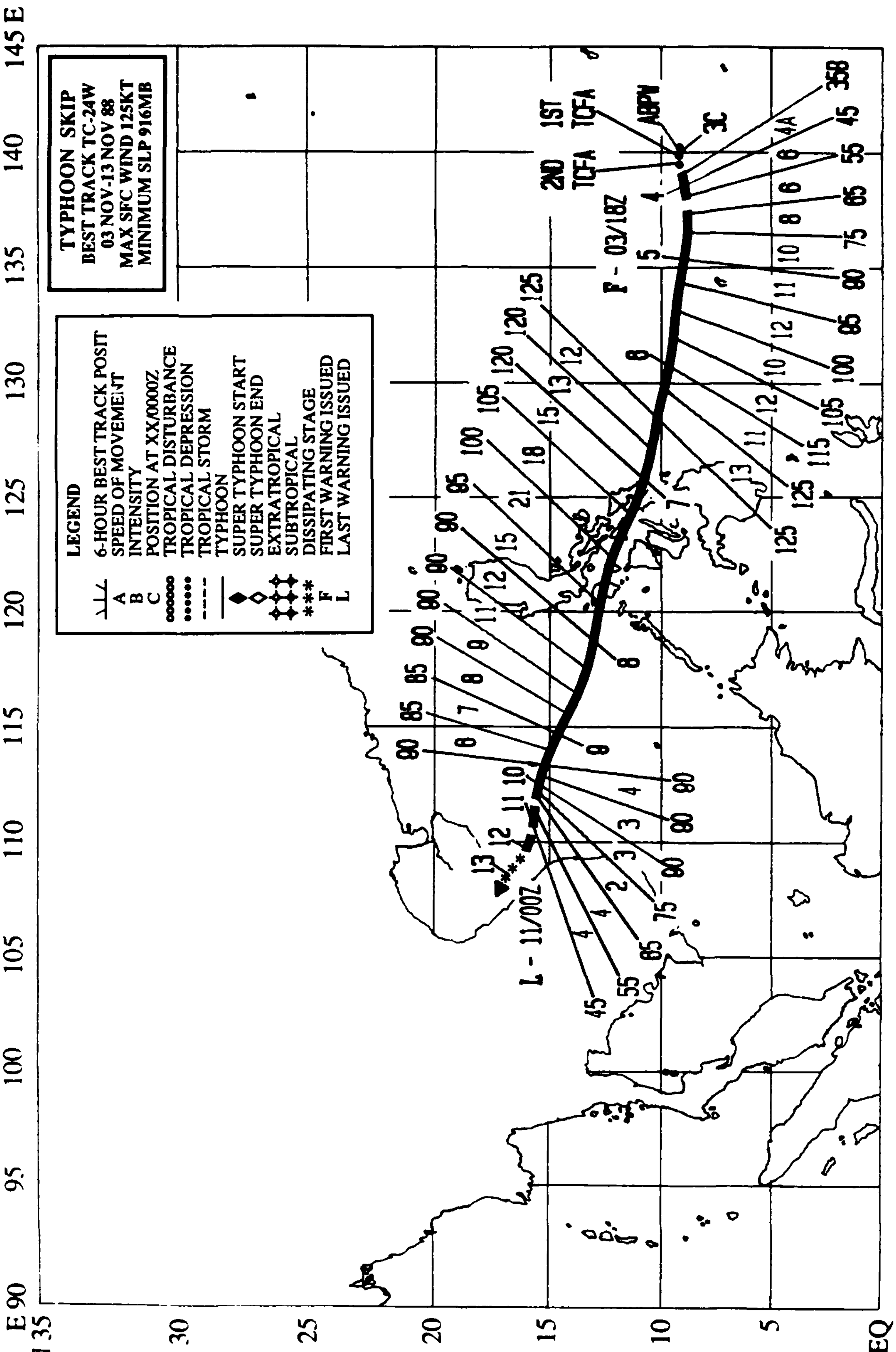
Figure 3-23-2. Convective bands brought prolonged torrential rains, high winds and hazardous surf conditions to western Luzon, as Ruby slowly entered the South China Sea (250048Z October DMSP visual imagery).

were left homeless. Also the freighter JET ANN FIVE sank near Bohol Island in the southern Philippines after encountering rough seas from Typhoon Ruby.

Entering the South China Sea at 250300Z, Ruby (Figure 3-23-2) slowed. As a result of Ruby's slow departure from Luzon, Subic Bay Naval Base and Clark Air Base received their worst weather following the passage of the typhoon's center. Bands of wind and rain from the southwest slammed into western Luzon, causing torrential downpours and strong, gusty winds. Peak gusts recorded were 69 kt (36 m/sec) at Subic Bay (Figure 3-23-3) and 46 kt (24 m/sec) at Clark Air Base. (These were the strongest winds reported at Clark Air Base since Super Typhoon Rita (1978) produced gusts to 58 kt (30 m/sec).)

Ruby then began to track toward the island of Hainan and made landfall at 280400Z. Interaction with the mountainous terrain of Hainan caused the tropical cyclone to weaken. The final warning was issued at 281800Z, after satellite imagery indicated the absence of central convection. Although Ruby's circulation dissipated over water, heavy rainshowers caused flash floods in northern Vietnam that killed at least 100 people, left thousands homeless and destroyed over 300,000 tons of agricultural produce.

Figure 3-23-3. Ruby's high winds caused widespread damage. This tree toppled into a housing unit. (Photo courtesy of the Naval Oceanography Command Facility, Cubi Point, Republic of the Philippines.)


TYPHOON SKIP
BEST TRACK TC-24W
03 NOV-13 NOV 88
MAX SFC WIND 125KT
MINIMUM SLP 916MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
1ST TCFA
2ND TCFA
ABPW
F - 03/18Z
L - 11/00Z
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ

TYPHOON SKIP (24W)

The first of two significant tropical cyclones to develop during November, Skip was a classic "straight runner" that covered over 2,000 nm (3,704 km) during its ten day lifetime. This typhoon was especially damaging to the Philippine Islands because it followed close behind Typhoons Ruby (23W) and Tess (25W).

On the first of November the northeast monsoon was well established across the South China Sea and southeastern Asia. Easterly tradewinds dominated the Philippine Sea north of the near-equatorial trough and a disturbance, that was to become Typhoon Tess (25W), was bringing more rain and wind to the central Philippine Islands. The next day Skip began as an area of convection in the monsoon trough about 360 nm (667 km) southwest of the island of Guam. After the convection had persisted for a day, the disturbance was listed on the Significant Tropical Weather Advisory at 030600Z. Visual satellite imagery indicated a well defined low-level cyclonic circulation immediately west of the curved band of convection (Figure 3-24-1). A satellite intensity analysis estimate of 30 kt (15 m/sec) surface winds precipitated the first Tropical Cyclone Formation Alert at 030700Z. The disturbance continued to develop and moved out of the Alert box, necessitating the issuance of a second Alert at 031400Z. Four hours later, after a satellite intensity estimate of 35 kt (18 m/sec),

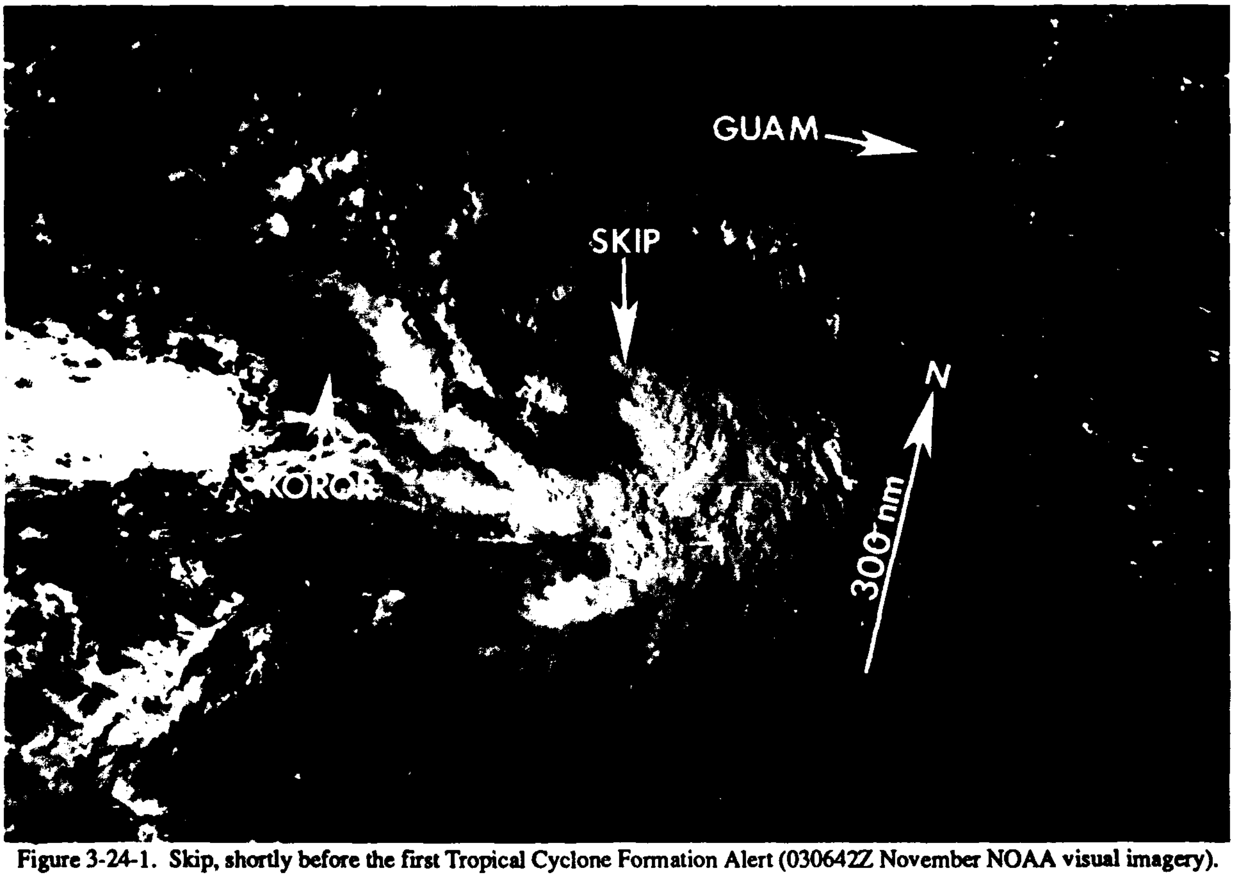


Figure 3-24-1. Skip, shortly before the first Tropical Cyclone Formation Alert (030642Z November NOAA visual imagery).

the first warning was issued. Skip (Figure 3-24-2) tracked westward and intensified, peaking in intensity at 125 kt (64 m/sec) at 060600Z.

As the typhoon approached the central Philippine Islands, it began to weaken and accelerate. The tropical cyclone reached a forward speed of 21 kt (39 km/hr), as it tracked across the island of Mindoro. The typhoon's trek through the Philippine Islands caused significant damage and loss of life. At least 104 people were killed by mudslides, floods and flying debris and another 95 persons were listed as missing. In all, Skip left over 600,000 homeless, caused extensive damage to coconut, rice and sugar crops, and widespread disruption of power and communication lines. Numerous watercraft were reported lost, missing or aground.

After weakening over the Philippine Islands, Skip slowed as it entered the South China Sea at 071800Z. During the next four days, Skip pushed west-northwestward along the southern side of the narrow subtropical ridge. At 100600Z the typhoon was downgraded to a tropical storm and further weakening led to the final warning at 110000Z. The remnants of Skip (Figure 3-24-3) drifted into the Gulf of Tonkin and dissipated.

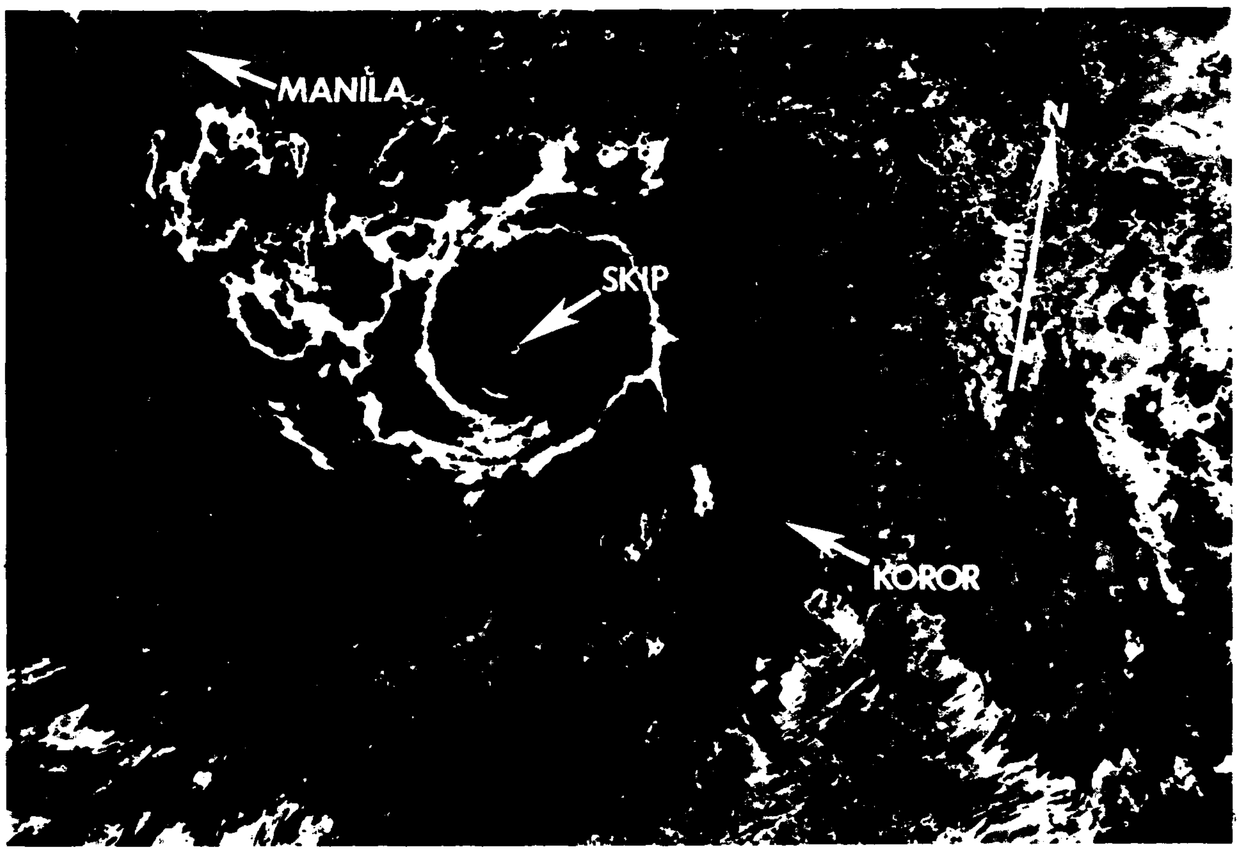


Figure 3-24-2. Typhoon Skip at peak intensity. Note the eye feature and symmetry of deep convection (061041Z November NOAA infrared imagery).

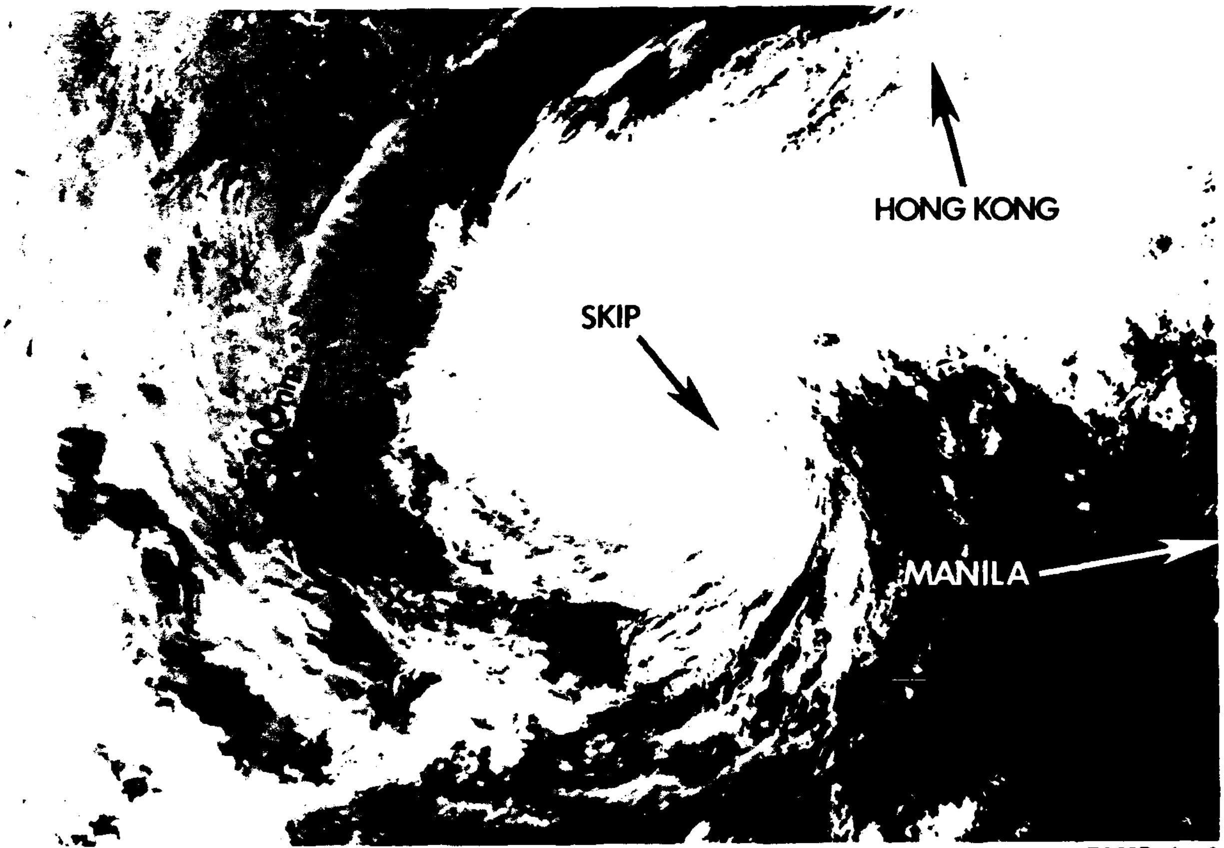
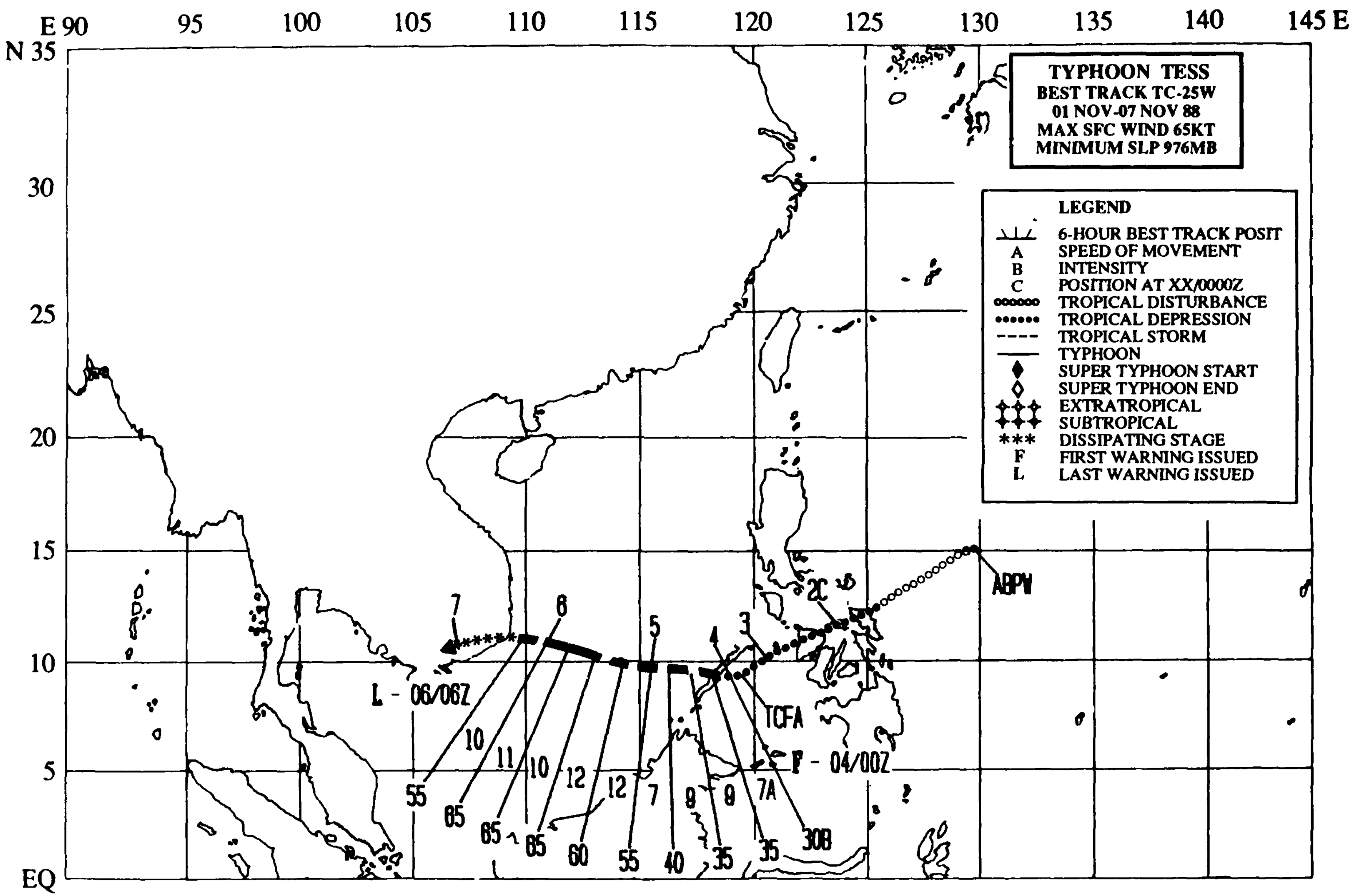


Figure 3-24-3. Skip maintains its organization, shortly after the final warning was issued (110157Z November DMSP visual imagery).


TYPHOON TESS
BEST TRACK TC-25W
01 NOV-07 NOV 88
MAX SFC WIND 65KT
MINIMUM SLP 976MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
ABPW
TCFA
F - 04/00Z
L - 06/06Z

TYPHOON TESS (25W)

The last of two significant tropical cyclones to occur during November, Tess developed slowly for three days before the first warning. Tess was the only tropical cyclone to track across southern Vietnam during 1988.

Tess' persistent area of convection was first mentioned on the Significant Tropical Weather Advisory at 010600Z. For the next three days the disturbance tracked southwestward along the edge of the deep northeasterly flow of the winter monsoon. Once across the rugged Philippine Islands and over open water in the Sulu Sea, the tropical cyclone (Figure 3-25-1) became more organized and required a Tropical Cyclone Formation Alert at 031730Z. A satellite intensity estimate of 30 kt (15 m/sec) prompted the first warning

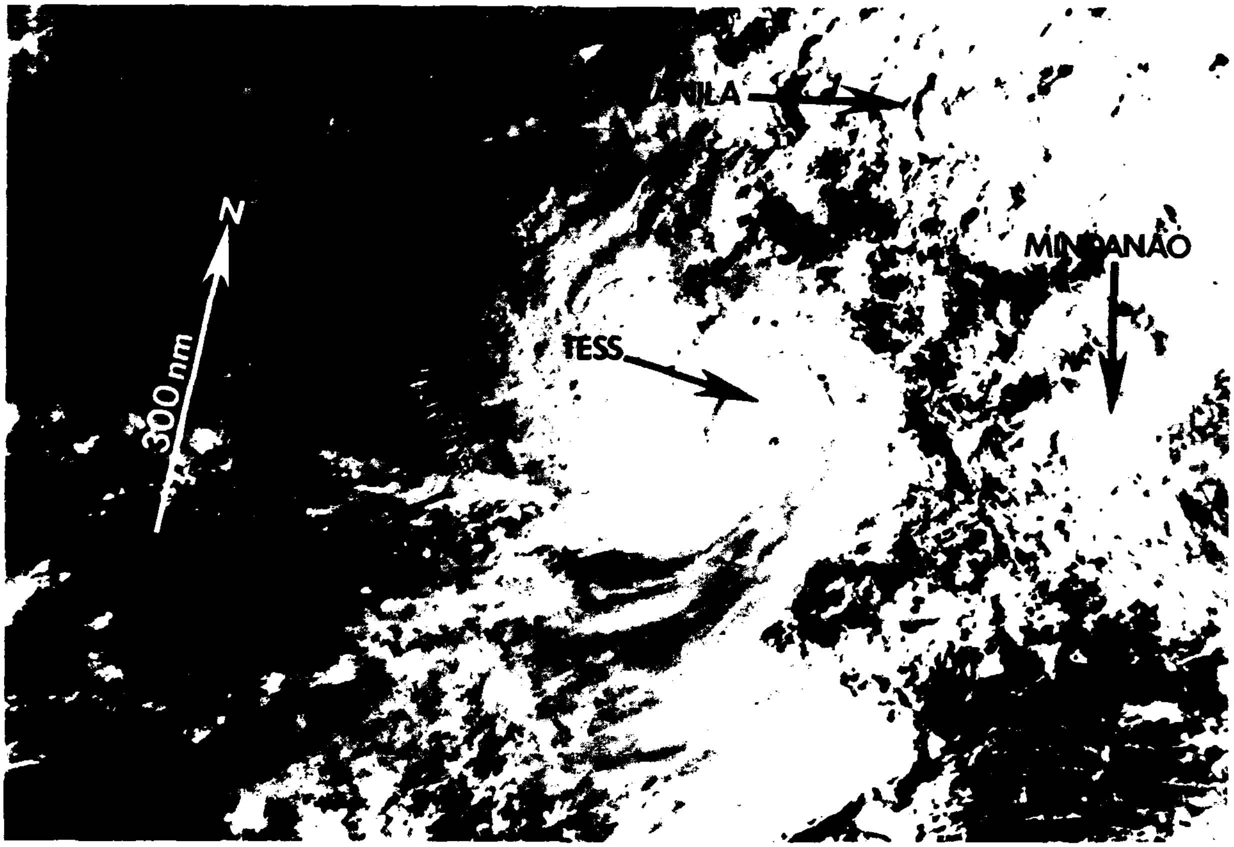


Figure 3-25-1. As a disturbance, Tess showed improved convection and organization as it entered the Sulu Sea (032221Z November DMSP visual imagery).

on Tropical Depression 25W (Figure 3-25-2) at 040000Z.

Almost immediately after the first warning, the track became westward. The most probable explanation for this change appeared in the low-level northeasterly gradient flow. The pressure gradient between the winter high and the lower pressure associated with Tess had sustained a persistent flow of at least 30 kt (15 m/sec) upstream of the tropical cyclone since 1 November. This upstream pressure gradient relaxed on 4 November and the gales clustered around Tess.

Along with this track change came intensification, as the system crossed Palawan Island and entered the South China Sea. At 040600Z, satellite intensity estimates indicated 35 kt (18 m/sec) surface winds and the tropical depression was upgraded to tropical storm intensity. The system (Figure 3-25-3) reached its peak intensity of 65 kt (33 m/sec) at 051200Z.

As Tess approached the coast of southern Vietnam, it began to weaken. The tropical cyclone was downgraded to tropical storm intensity and finalled at 060600Z. The remnants of Tess continued to track westward across the Mekong river delta. No reports of damage or loss of life were received.

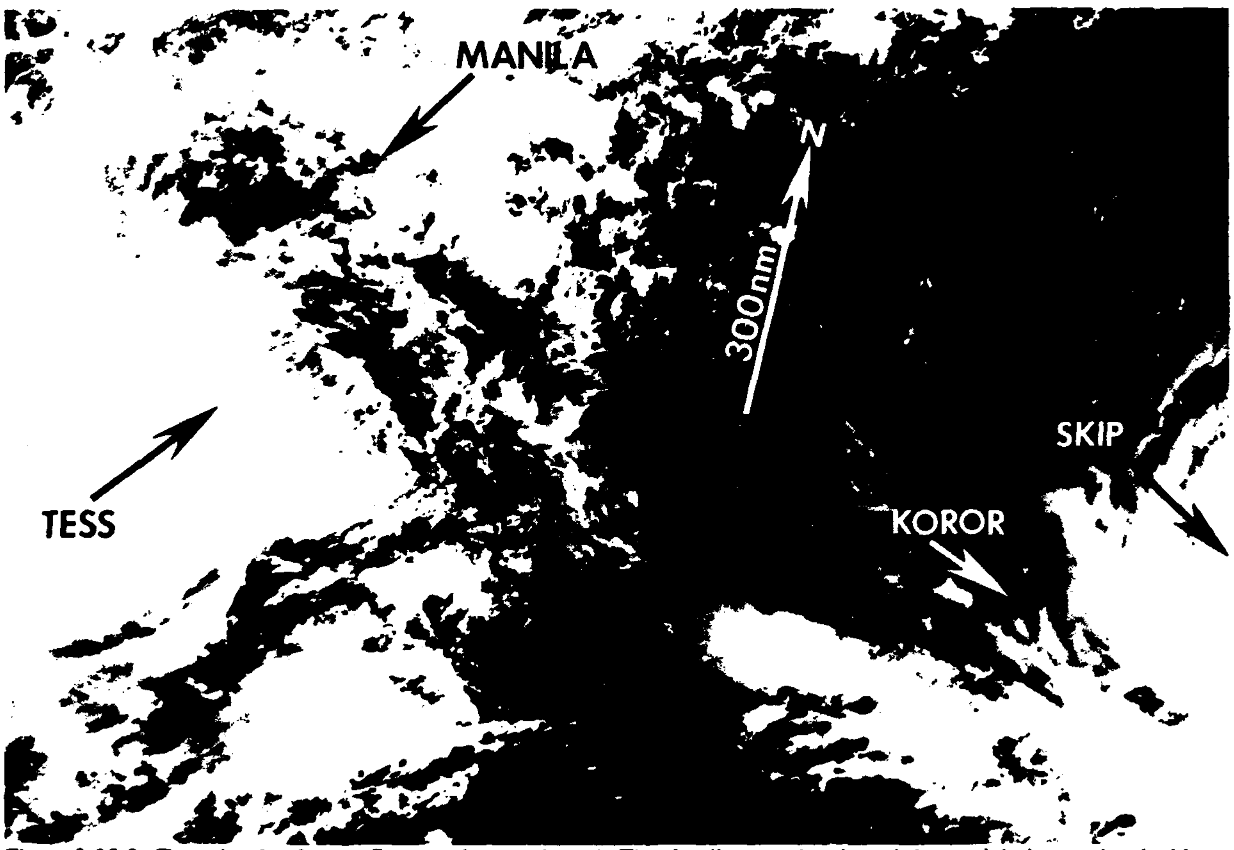


Figure 3-25-2. Tess, shortly after the first warning was issued. The cloudiness at the picture's lower right is associated with Skip (24W) (040053Z November DMSP visual imagery).

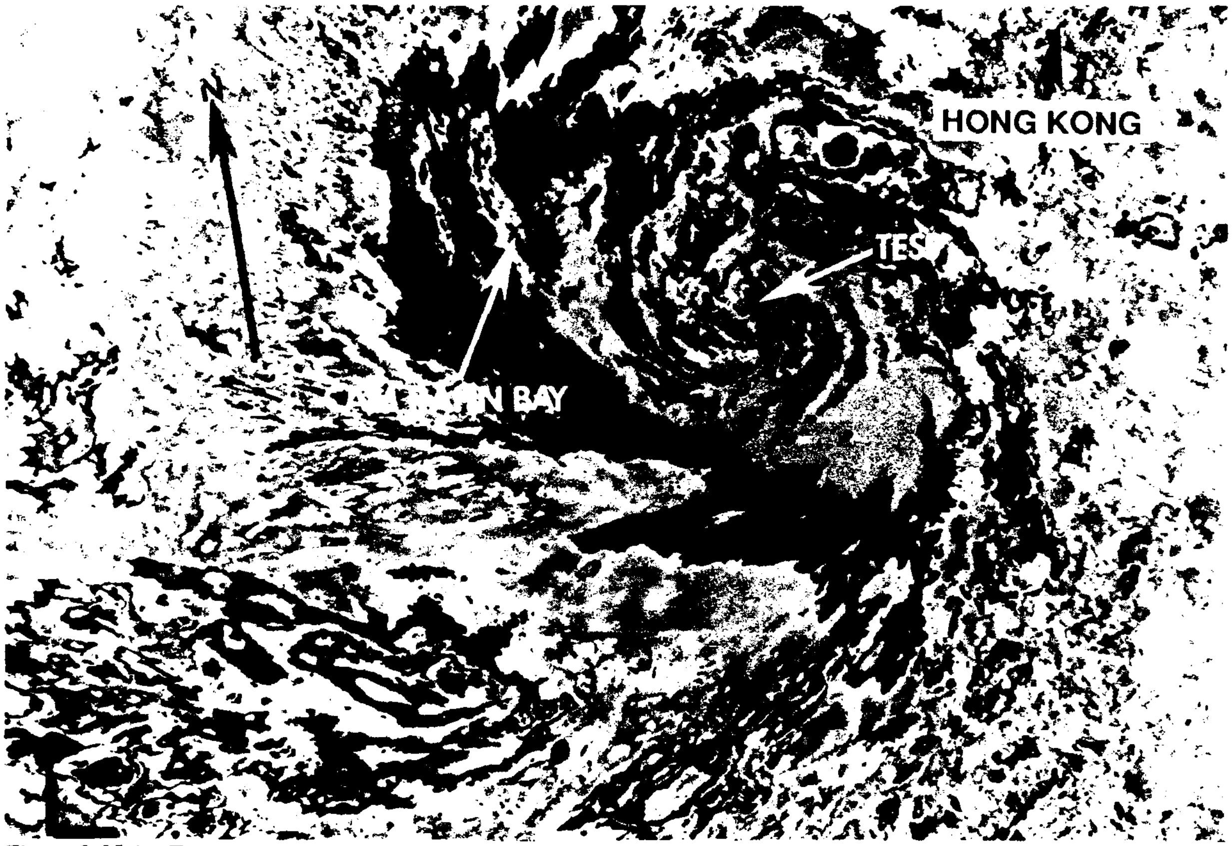
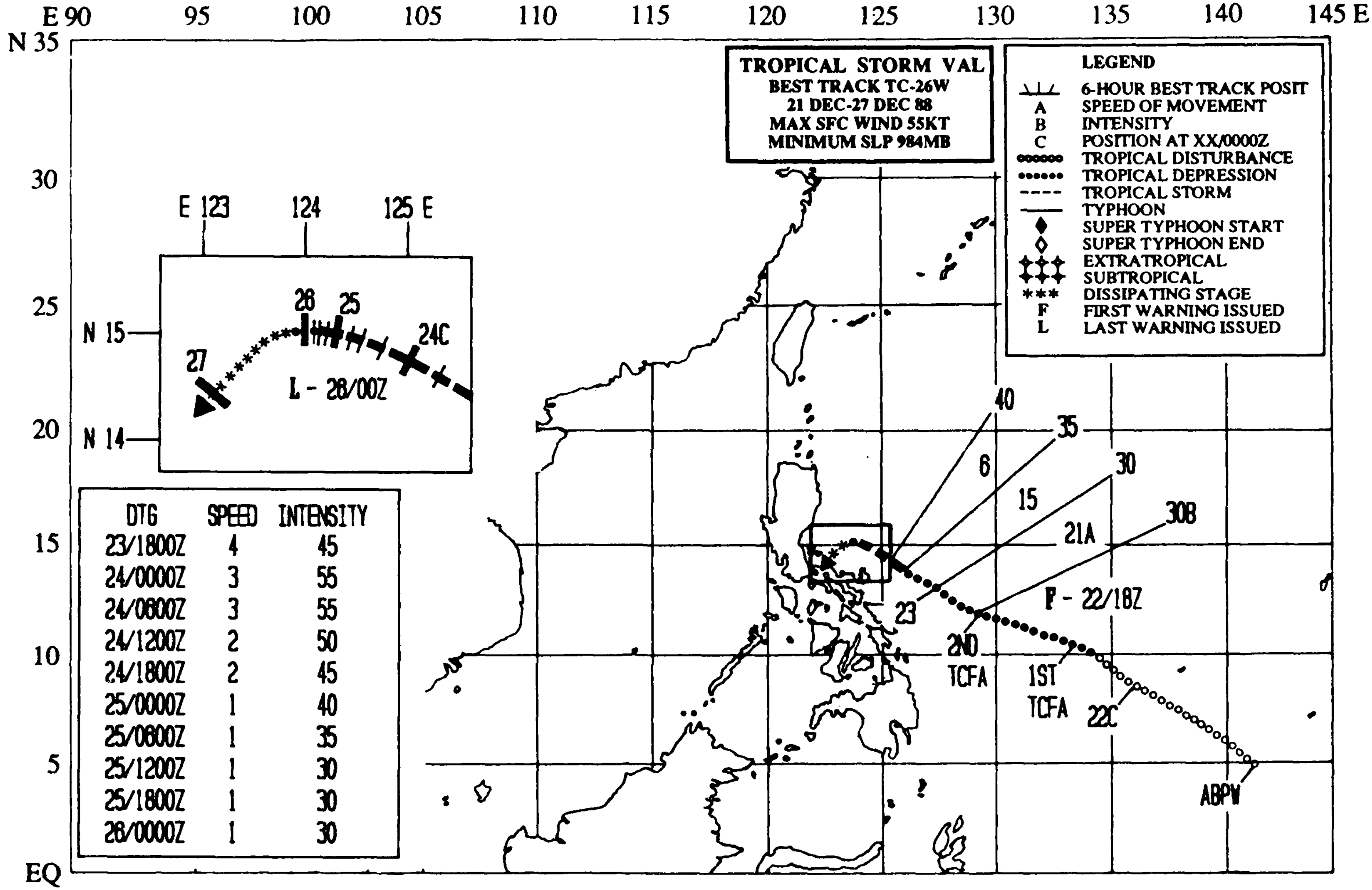


Figure 3-25-3. Tess just before reaching its peak intensity in the South China Sea (051054Z November DMSP infrared imagery).



DTG	SPEED	INTENSITY
23/1800Z	4	45
24/0000Z	3	55
24/0600Z	3	55
24/1200Z	2	50
24/1800Z	2	45
25/0000Z	1	40
25/0600Z	1	35
25/1200Z	1	30
25/1800Z	1	30
26/0000Z	1	30

TROPICAL STORM VAL (26W)

Tropical Storm Val (26W) was the final significant tropical cyclone of 1988 and the only storm to develop during December. It proved difficult to position and hard to forecast. In less than 24-hours, Val decelerated from a 25 kt (46 km/hr) to quasi-stationary. Also, the system's cirrus outflow prevented timely detection of shearing and decoupling of the low-level circulation center from the central convection.

On 13 December a massive outbreak of polar air started to push southeastward from Asia across the Philippine Sea. By 18 December the leading edge of the air mass stretched from the southern Philippine Islands to the northern Marianas and northeastward. As the major thrust of the cold air diminished, the southern Philippine Sea filled with deep convection and a near-equatorial trough formed. Multiple low-level cyclonic circulations appeared in the trough with nearby gales to the north due to the strong northeast monsoon. Finally, the convection began to consolidate in the western Caroline Islands and the area was initially mentioned at 210600Z on the Significant Tropical Weather Advisory. The convection continued to organize and a Tropical Cyclone Formation Alert was issued at 220700Z based on satellite imagery that indicated an increase in upper-level organization. Plus, surface synoptic reports revealed pressures as low as 1005 mb and 20 kt (10 m/sec) westerly winds to the south of the circulation center.

A second Alert was issued at 221800Z to cover the unusually rapid movement — 25 kt (46 km/hr) — of the circulation to the west. Still, the area (Figure 3-26-1) developed, and the upper-level outflow and surface circulation

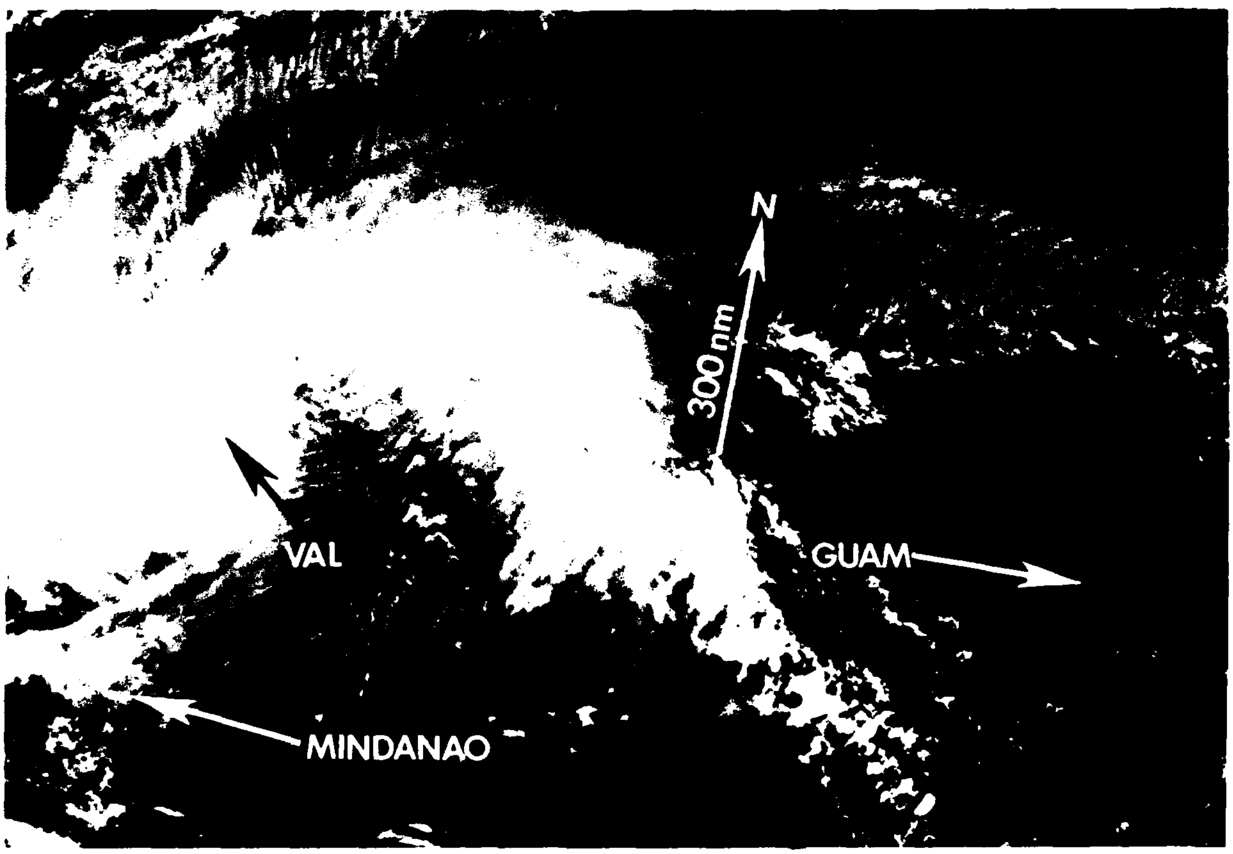


Figure 3-26-1. Val with its major convective band (230429Z December NOAA visual imagery).

improved. The first warning followed close behind with a valid time at 221800Z based on a satellite intensity analysis estimate of 30 kt (15 m/sec). Then Val (26W) began to decelerate and intensify. It reached a peak intensity of 55 kt (28 m/sec) at 240000Z (Figure 3-26-2).

As the intensity peaked and forward motion ground to a halt on 24 December, high cloudiness obscured the low-level circulation center. The deep central convection and upper-level circulation center, which were the targets for remote sensing, tracked northward. The shallow system (Figure 3-26-3) continued to weaken and the final warning was issued at 260000Z. The dissipating low-level circulation center accelerated to the southwest along the eastern boundary of the northeast monsoon. No reports of damage or loss of life were received.

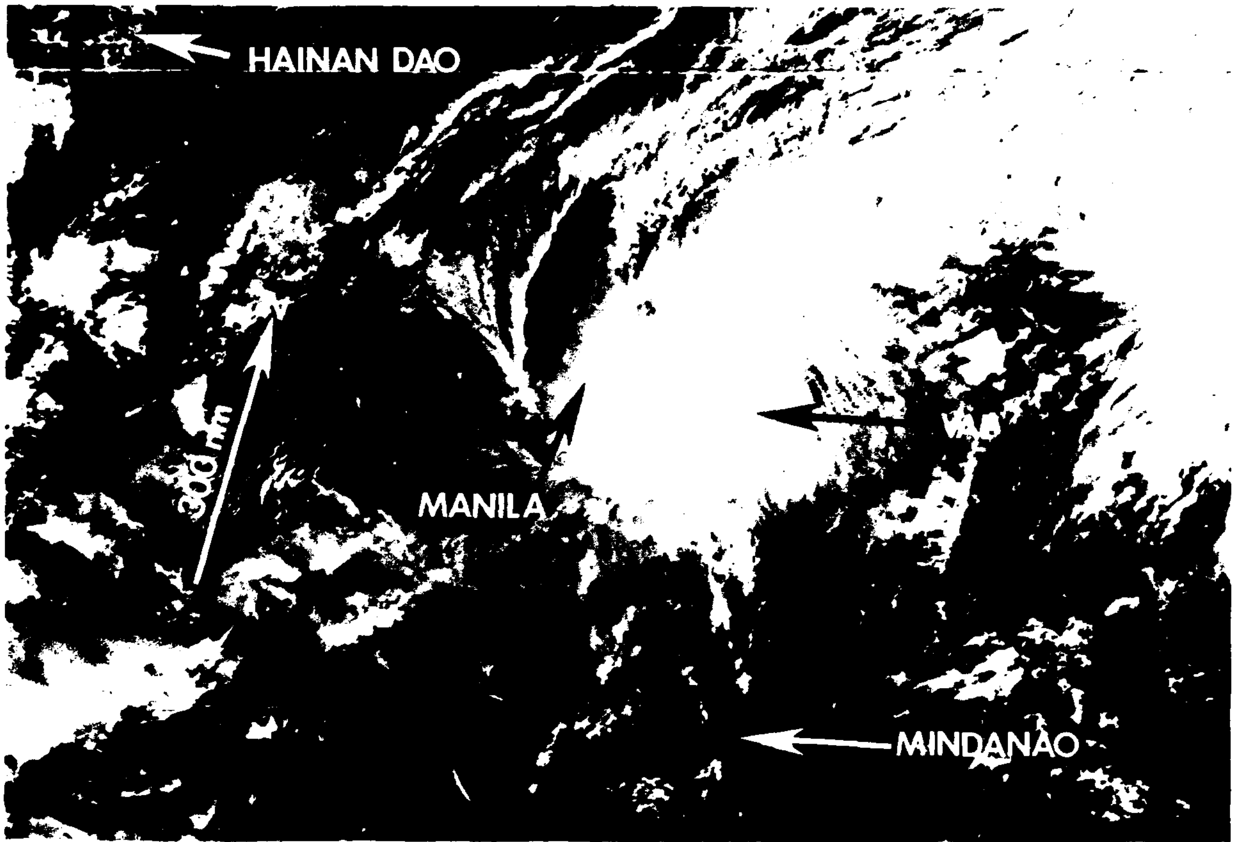


Figure 3-26-2. Tropical Storm Val at maximum intensity (240114Z December DMSP visual imagery).

Figure 3-26-3. Val's exposed low-level circulation center appears at the southern edge of the central cloud mass (250054Z December DMSP visual imagery).

3. NORTH INDIAN OCEAN TROPICAL CYCLONES

Five significant tropical cyclones developed in the North Indian Ocean during 1988. This was average and well below 1987's all-time record of eight tropical cyclones. The only tropical cyclone to form in the Arabian Sea, Tropical Cyclone 01A, was also the only cyclone of the spring transition season. In contrast, the other four tropical cyclones were all part of the fall transition season and occurred in the Bay of Bengal. The most damaging of these, Tropical Cyclone 04B, was one of the most intense to strike the Ganges River delta in this century. The spring and fall in the North Indian Ocean are periods of transition between major climatic controls - the summer, or southwest monsoon, and the winter, or northeast monsoon - and the most favorable seasons for tropical cyclone formation. Tables 3-5 and 3-6 provide a summary of information for 1988 and comparison with earlier years.

TABLE 3-5

1988 SIGNIFICANT TROPICAL CYCLONES
NORTH INDIAN OCEAN

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
TC 01A	10 JUN - 12 JUN	10	35 (18)	996
TC 02B	18 OCT - 19 OCT	3	35 (18)	996
TC 03B	18 NOV	3	55 (28)	984
TC 04B	24 NOV - 29 NOV	22	110 (57)	933
TC 05B	07 DEC - 08 DEC	6	45 (23)	991
	TOTAL	44		

TABLE 3-6

FREQUENCY OF NORTH INDIAN OCEAN
TROPICAL CYCLONES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
1987	0	1	0	0	0	2	0	0	0	1	2	2	8
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
(1975-1988) AVERAGE	0.1	0.1	0.0	0.1	0.6	0.5	0.0	0.1	0.2	1.0	1.5	0.5	4.7
TOTAL	2	1	0	1	9	7	0	1	3	14	21	7	66

* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUNE 1971 FOR THE BAY OF BENGAL, EAST OF 90° EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PART OF THE BAY OF BENGAL. COMMENCING WITH THE 1975 TROPICAL CYCLONE SEASON, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PART OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA. ALL FOUR TROPICAL CYCLONE FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES. FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1988, EXCEPT TROPICAL CYCLONE 02B.

WARNINGS: NUMBER OF CALENDAR WARNING DAYS: 14
THERE WERE NO CALENDAR WARNING DAYS WITH TWO OR MORE TROPICAL CYCLONES.

4. NORTH INDIAN OCEAN CLIMATOLOGY

This climatology* of peak tropical cyclone intensity for the North Indian Ocean was prepared from data in the 1971 through 1988 Annual Tropical Cyclone Reports and Annual Typhoon Reports. JTWC became responsible for the Bay of Bengal east of 90° East longitude on 4 June 1971. Table 3-7 lists the number of significant tropical cyclones by peak intensity and month for the Bay of Bengal. JTWC became responsible for the Arabian Sea in 1975; thus the Arabian Sea data are from 1975 through 1988. Table 3-8 lists the number of significant tropical cyclones by peak intensity and month for the Arabian Sea.

Note: data for tropical cyclones that passed from the Bay of Bengal into the Arabian Sea were included in the statistics for both basins when the peak intensity was 35 kt (18 m/sec) or greater in both basins. If the peak intensity was 35 kt (18 m/sec) or greater and the tropical cyclone transitioned from one month to another, it was included in each month's statistics. Tropical cyclones with less than 35 kt (18 m/sec) were not considered. The data set for 1971 through 1974 in the Bay of Bengal is incomplete, because the AOR at that time only included tropical cyclones that developed or tracked east of 90° East longitude. These years are included since they provide limited additional data on the peak intensities.

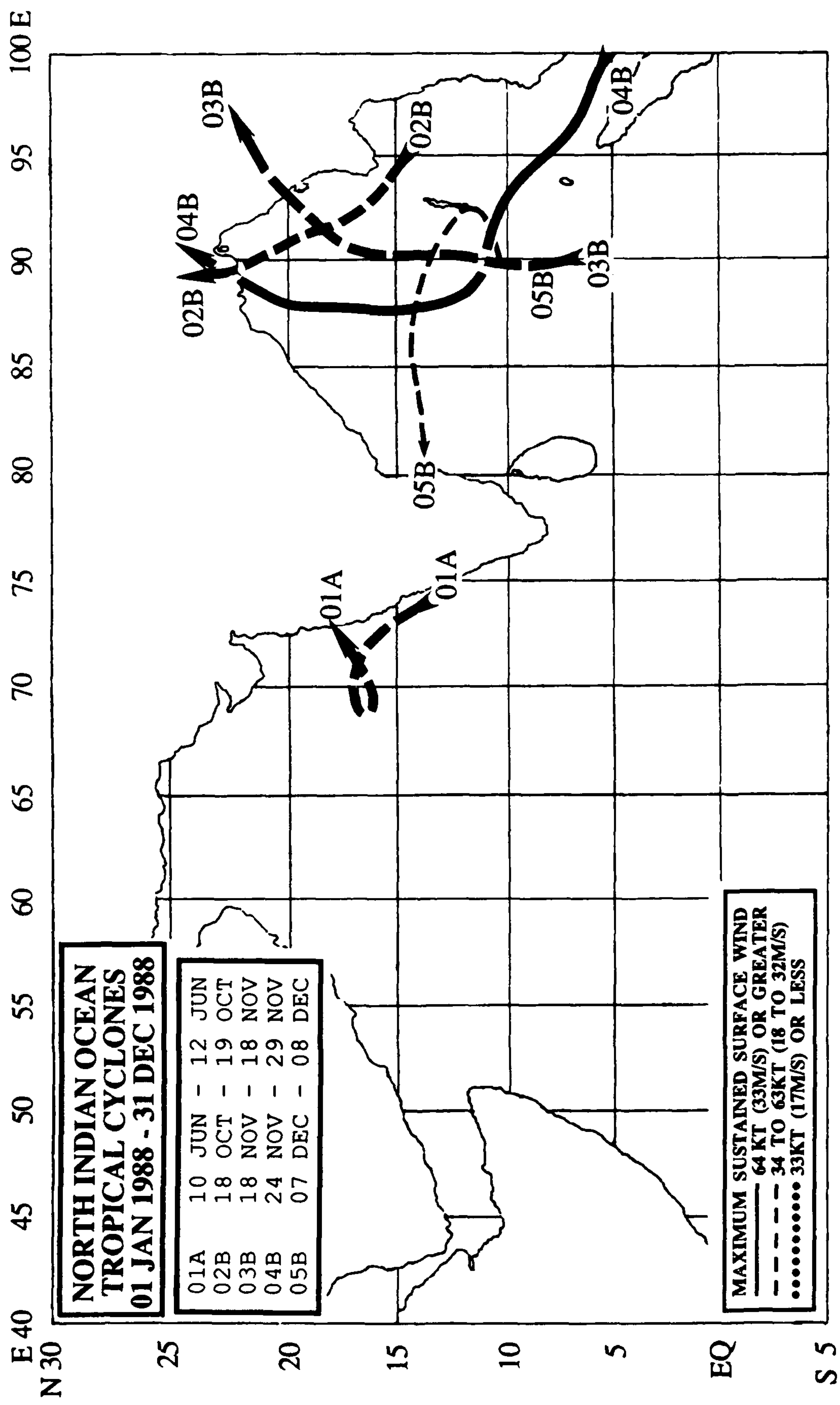
* Climatology prepared by Capt John Rogers, USAF.

TABLE 3-7 BAY OF BENGAL (1971-1988)

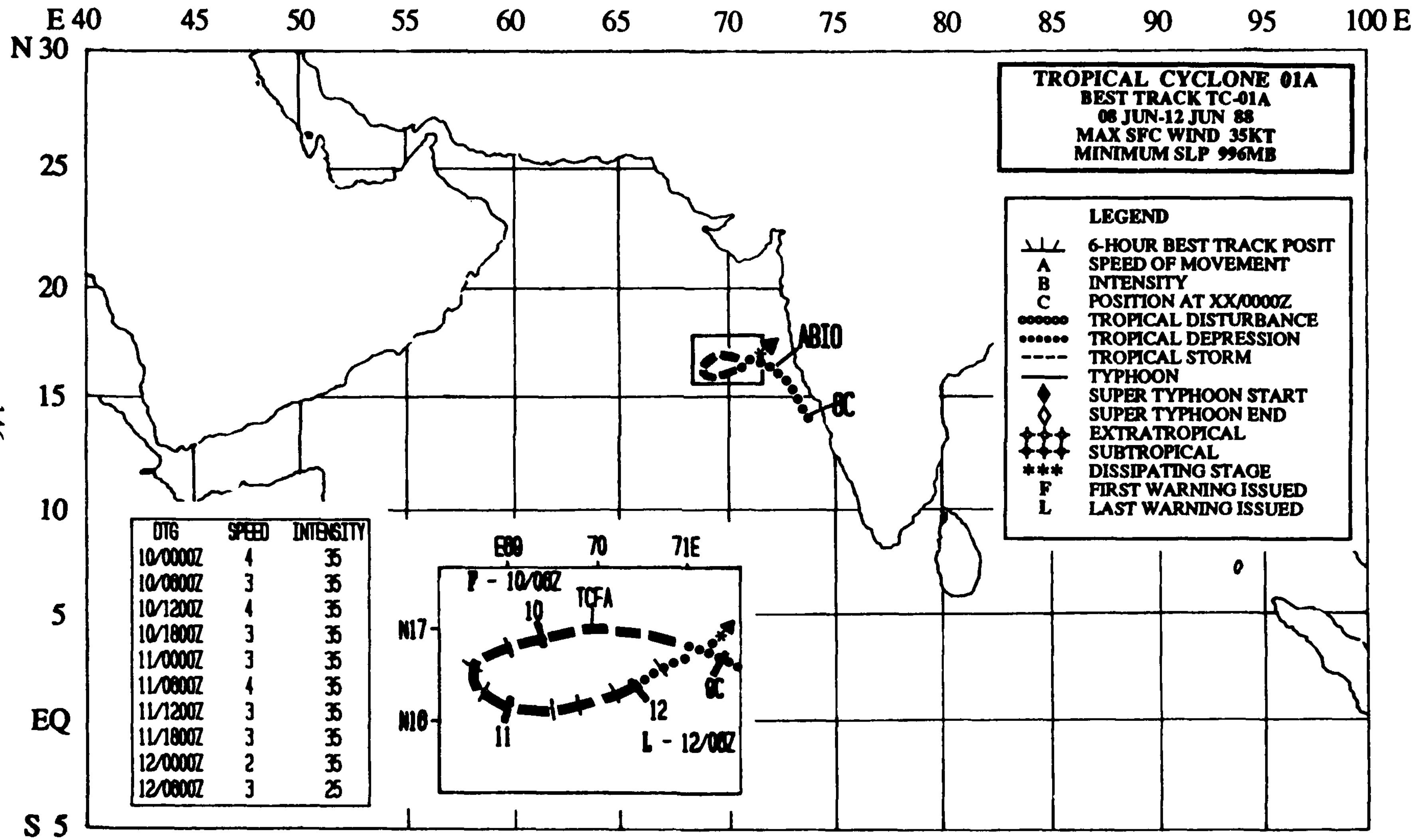
Peak Intensity (kt)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
125					1								1
120													0
115											1		1
110											1		1
105													0
100										1			1
95											1		1
90											1		1
85				1	1						1		3
80									1				1
75					1						2	2	5
70									1		1		2
65											1		1
60					3						1	1	5
55		1				2					5	1	9
50				1	1					5	3	1	11
45	1									2	1	1	5
40	1								1	4			6
35	1									2		3	6
Total	3	1	0	2	7	2	0	0	3	14	19	9	60

TABLE 3-8 ARABIAN SEA (1975-1988)

Peak Intensity (kt)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
95					1								1
90											1		1
85													0
80										1	1		2
75													0
70											1		1
65													0
60						1				1	1	1	4
55									1				1
50					1	2				1			4
45					1			1			1	1	4
40						1					1		2
35						1					2		3
Total	0	0	0	0	3	5	0	1	1	3	8	2	23



NORTH INDIAN OCEAN
TROPICAL CYCLONES
01 JAN 1988 - 31 DEC 1988
01A 10 JUN - 12 JUN
02B 18 OCT - 19 OCT
03B 18 NOV - 18 NOV
04B 24 NOV - 29 NOV
05B 07 DEC - 08 DEC
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
01A
02B
03B
04B
05B
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5



DTG	SPEED	INTENSITY
10/0000Z	4	35
10/0600Z	3	35
10/1200Z	4	35
10/1800Z	3	35
11/0000Z	3	35
11/0600Z	4	35
11/1200Z	3	35
11/1800Z	3	35
12/0000Z	2	35
12/0600Z	3	25

TROPICAL CYCLONE 01A

Tropical Cyclone 01A was the first and only significant tropical cyclone to develop in the North Indian Ocean during the spring transition season. Due to persistent upper-level cloudiness (Figure 3-01A-1) the system proved difficult to position, track and forecast. Tropical Cyclone 01A was initially identified as an area of convection about 240 nm (444 km) south of Bombay, India on 8 June by the Air Force Global Weather Central. It was first mentioned on the Significant Tropical Weather Advisory at 081800Z. After satellite imagery indicated a central dense overcast, increased convection and upper-level organization, a Tropical Cyclone Formation Alert was issued at 091430Z. The system's organization continued

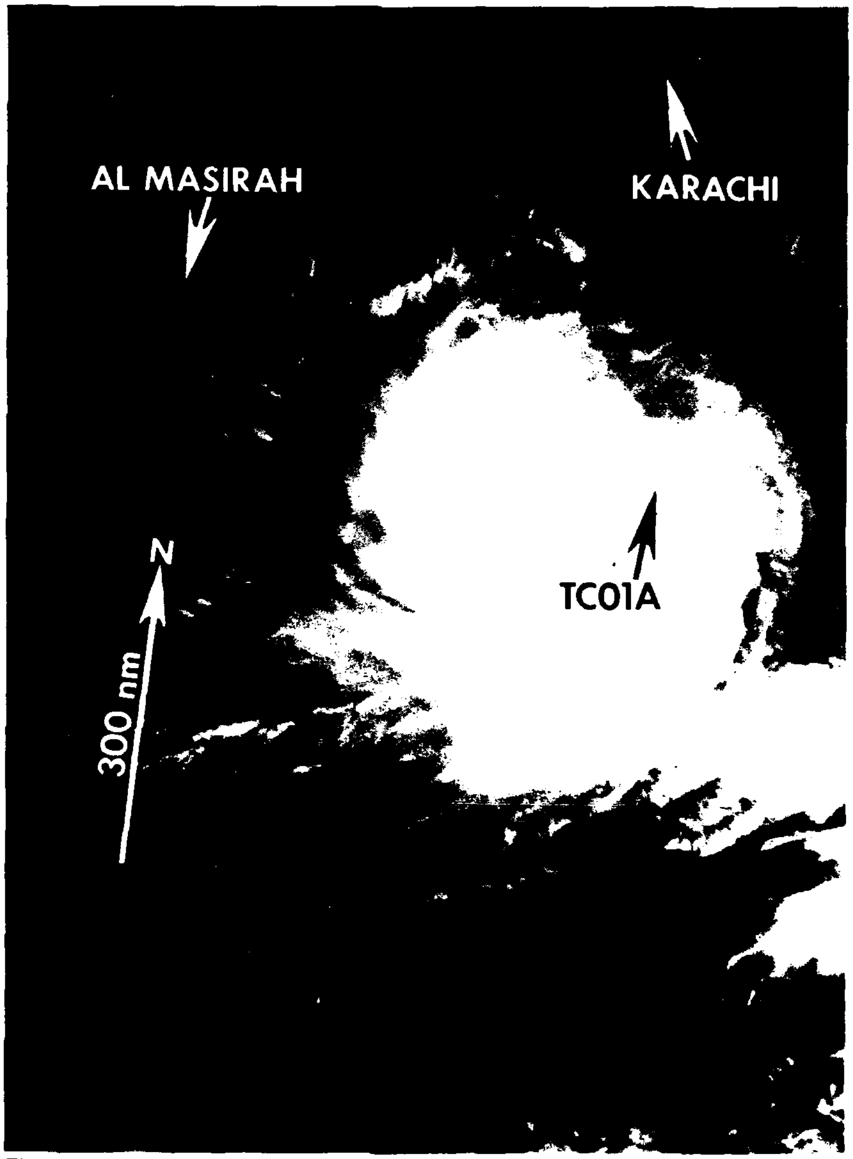


Figure 3-01A-1. The bright, cold cloudiness persisted over and masked the low-level circulation (100530Z June DMSP infrared imagery).

to improve and JTWC issued its first warning at 100000Z when satellite imagery and synoptic data indicated an intensity of 35 kt (18 m/sec). Finally, vertical wind shear exposed the low-level circulation center. As a result, the 110000Z warning was amended and relocated - the circulation center appeared 240 nm (407 km) east-southeast of the upper-level circulation center (Figure 3-01A-2). Unfavorable conditions aloft continued and at 120600Z the final warning was issued, as the tropical cyclone dissipated over water.

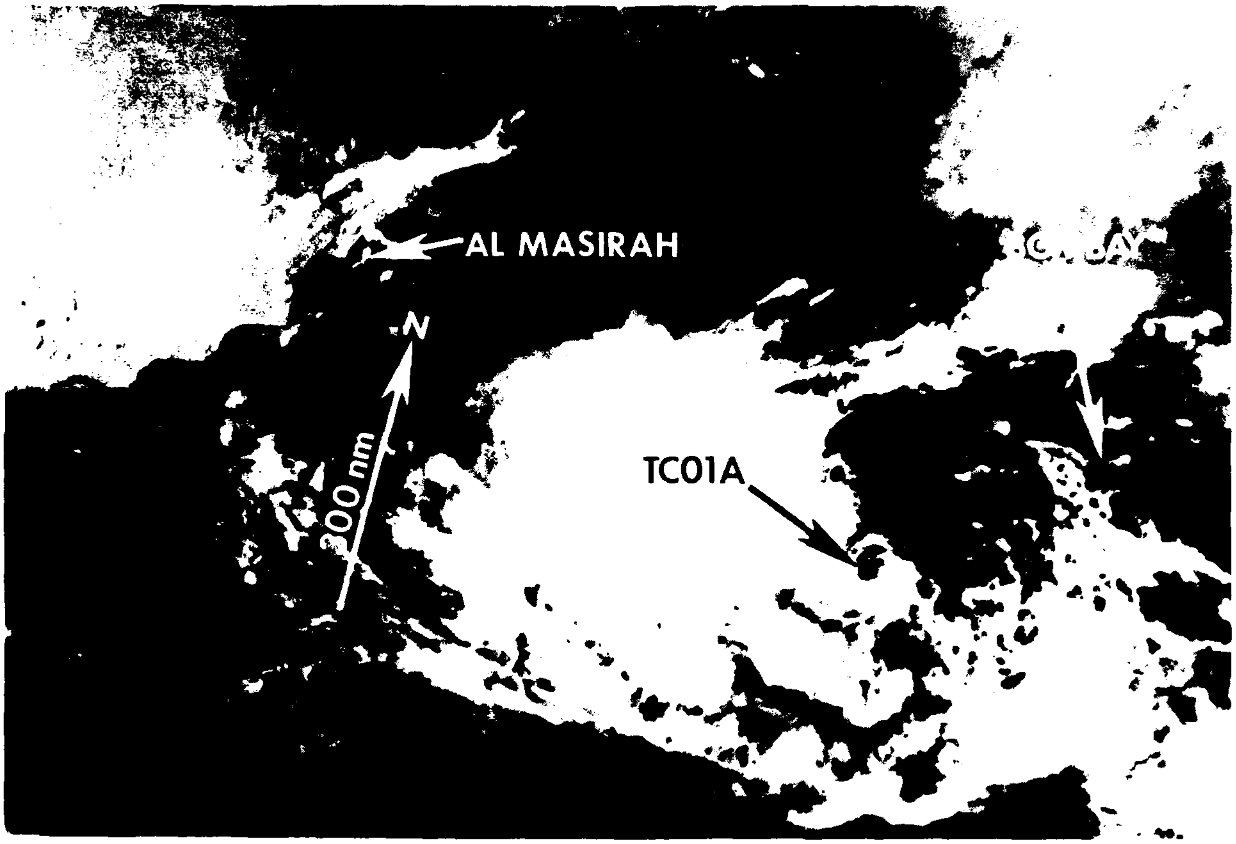
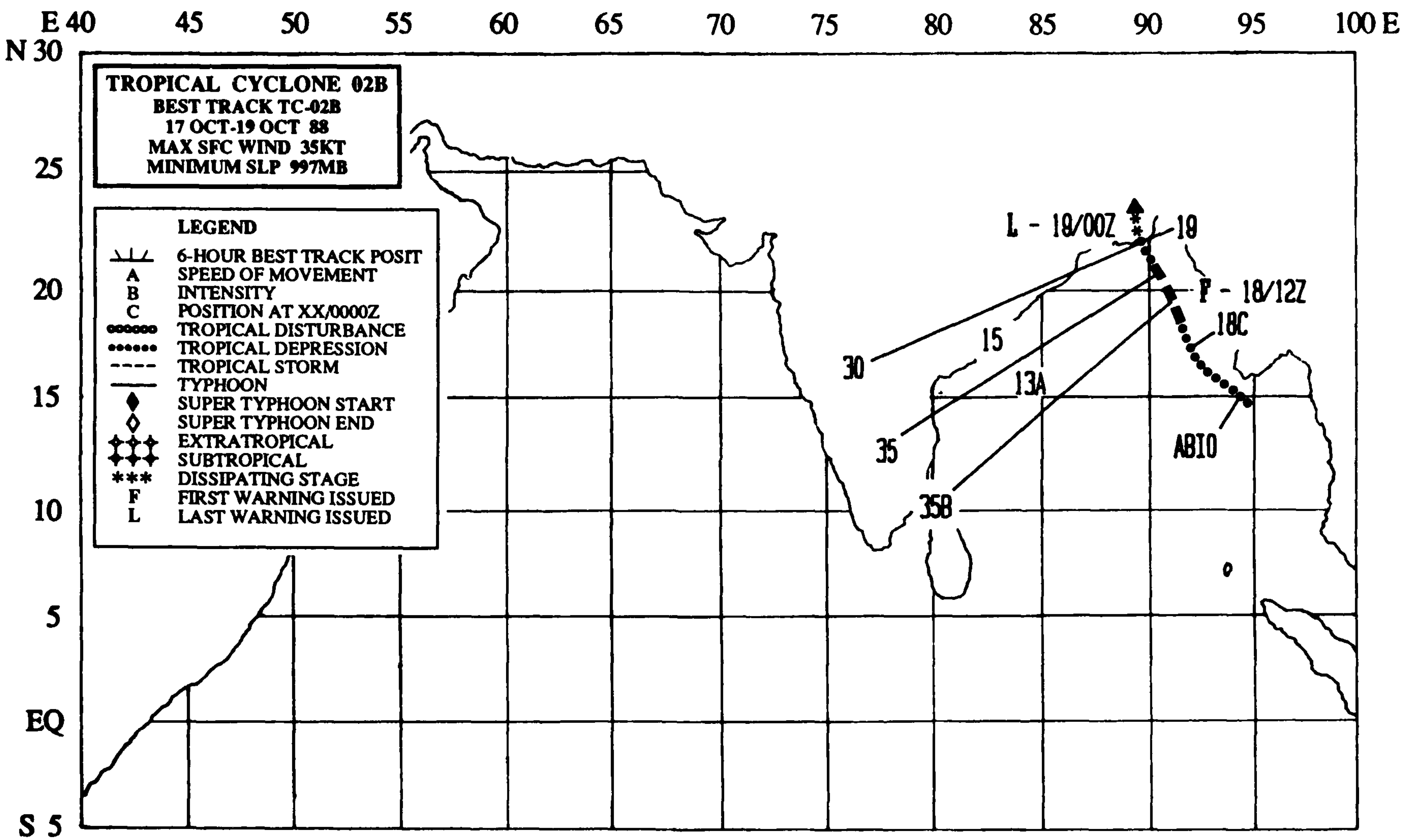


Figure 3-01A-2. The low-level circulation is exposed. Note the dust blowing seaward from coastal areas to the north (110511Z June DMSP visual imagery).

Intentionally left blank.



TROPICAL CYCLONE 02B
BEST TRACK TC-02B
17 OCT-19 OCT 88
MAX SFC WIND 35KT
MINIMUM SLP 997MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
L - 19/00Z
19
F - 18/12Z
18C
ABIO
30
15
13A
35
35B

TROPICAL CYCLONE 02B

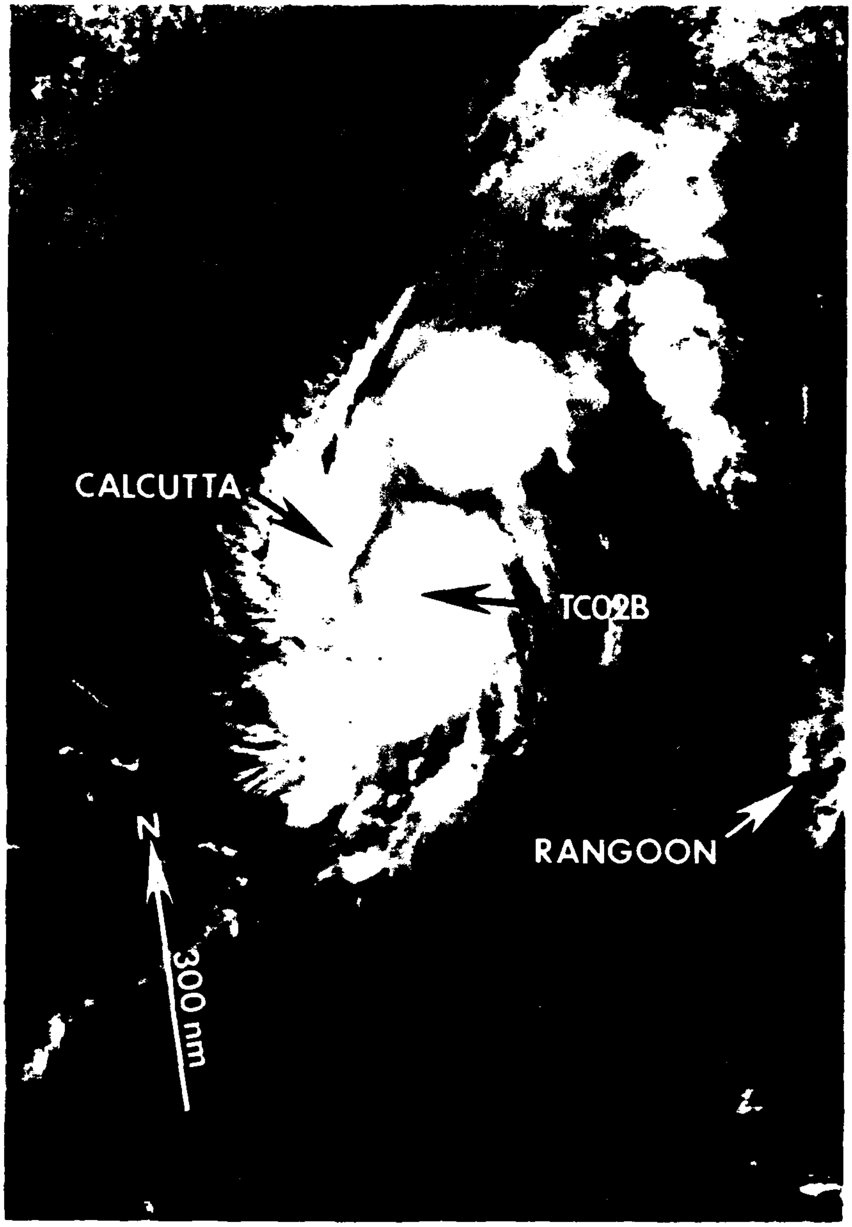
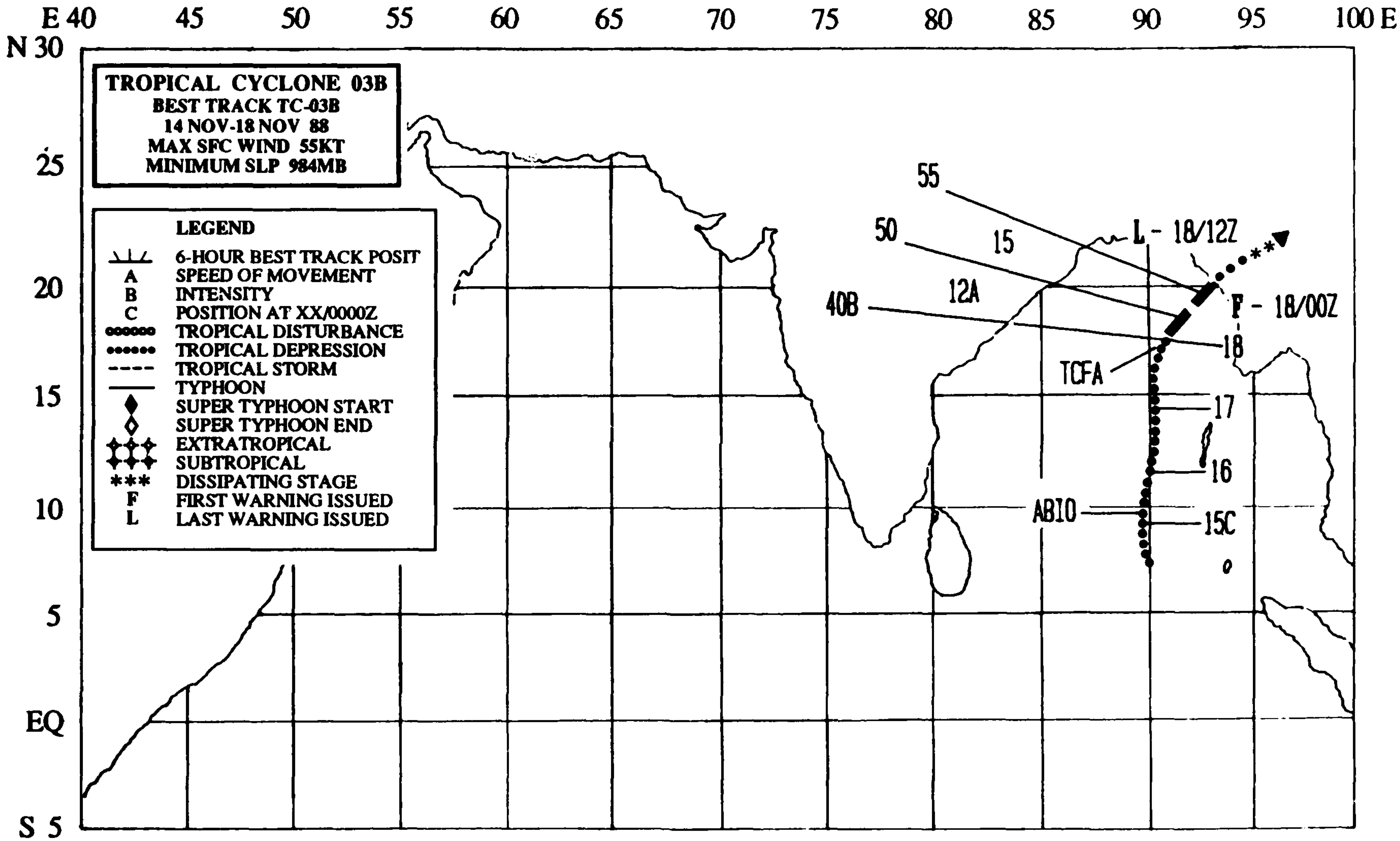


Figure 3-02B-1. The tropical disturbance was first detected 135 nm (250 km) southwest of Rangoon, Burma and the Significant Tropical Weather Advisory was reissued at 170800Z to include it. The first warning followed at 181200Z as the cyclone reached a peak intensity of 35 kt (18 m/sec). Once onshore, the final warning was issued at 190000Z. Press releases cited at least 35 deaths, more than 1000 injuries and an estimated 1500 missing. The fishing fleet was particularly hard hit and there were press reports of 15 ft (4.6 m) waves and winds as high as 65 kt (33 m/sec). The above photo shows Tropical Cyclone 02B at the coast of Bangladesh (182219Z October NOAA visual imagery).


TROPICAL CYCLONE 03B
BEST TRACK TC-03B
14 NOV-18 NOV 88
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
55
50
15
12A
40B
L - 18/12Z
F - 18/00Z
18
TCFA
17
16
ABIO
15C

TROPICAL CYCLONE 03B

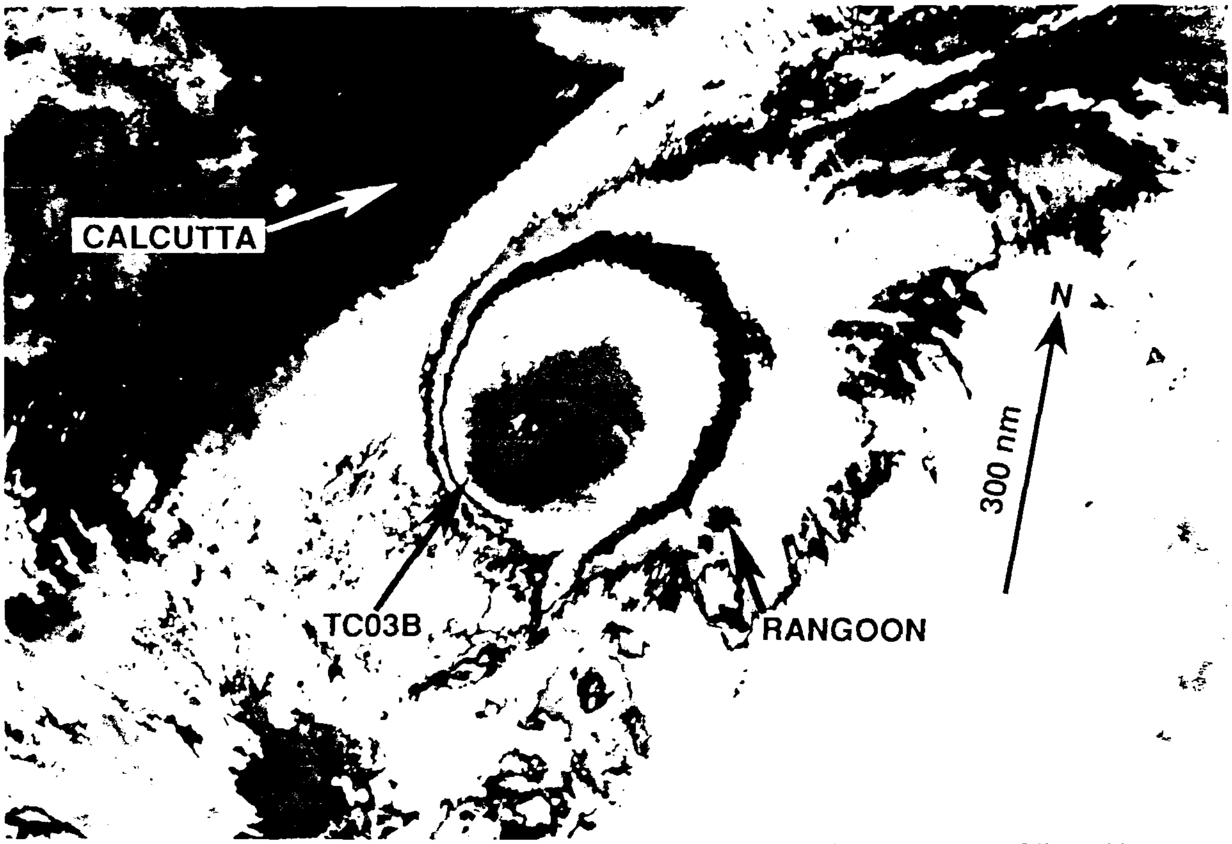
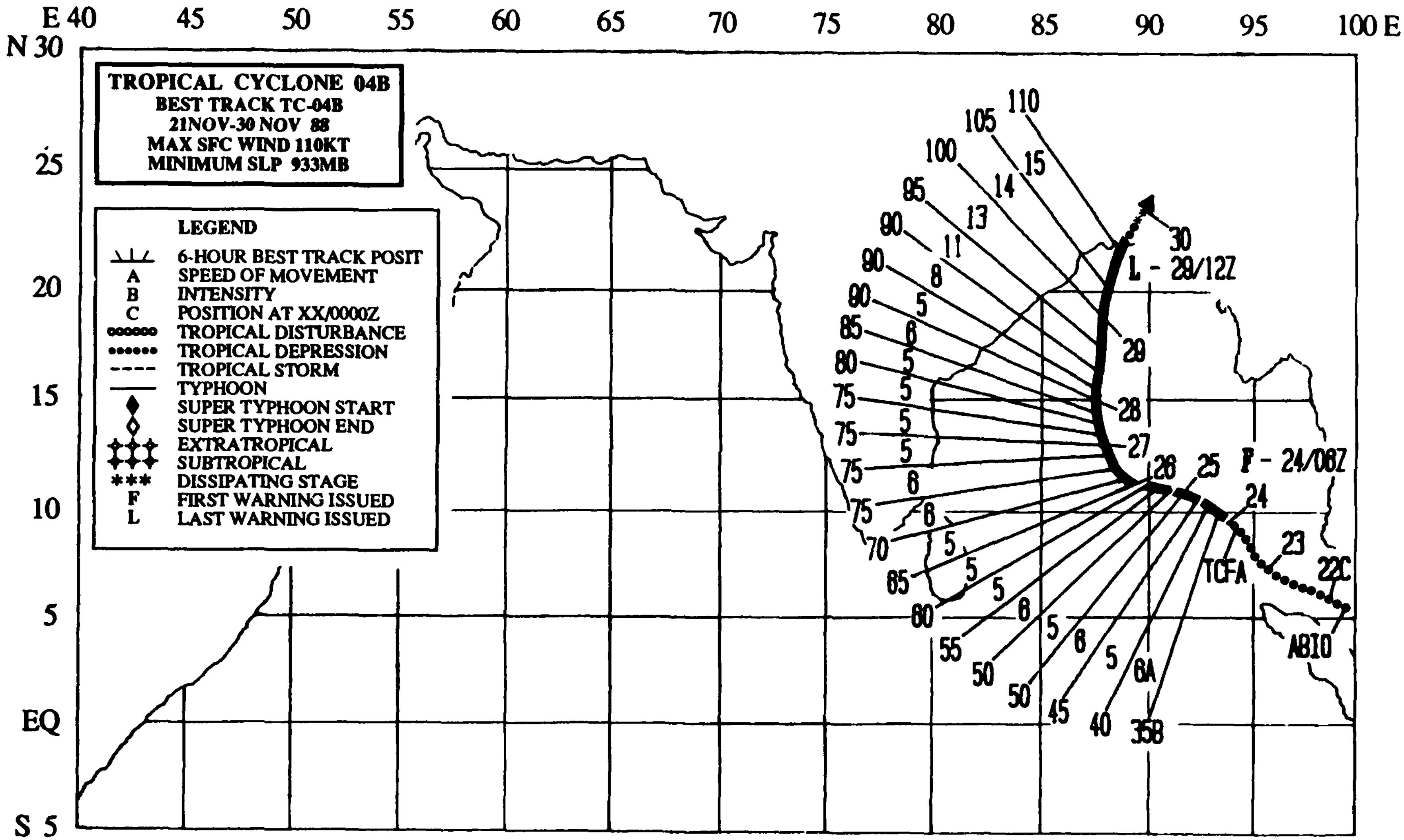


Figure 3-03B-1. The second significant tropical cyclone to develop in the Bay of Bengal during the fall transition season, Tropical Cyclone 03B was the first to make landfall over Burma. By 12 November the presence of Tropical Cyclone 01S in the South Indian Ocean strengthened the low-level westerlies along the equator and across the southern portion of the Bay of Bengal. As Tropical Cyclone 01S moved west-southwestward, a disturbance organized north of the equator. The Significant Tropical Weather Advisory was reissued at 150600Z to describe the circulation. The system tracked northward around the western edge of a subtropical anticyclone. At 172230Z, a Tropical Cyclone Formation Alert was issued after satellite intensity analysis indicated sustained surface winds of 30 kt (15 m/sec). The disturbance's organization continued to improve and, at 180000Z, the first warning was issued. The final warning followed 12-hours later as Tropical Cyclone 03B made landfall on the coast of Burma. The enhanced infrared picture above shows the tropical cyclone during intensification (180309Z November DMSP infrared imagery).


TROPICAL CYCLONE 04B
BEST TRACK TC-04B
21NOV-30 NOV 88
MAX SFC WIND 110KT
MINIMUM SLP 933MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 28/12Z
F - 24/06Z
TCFA
ABIO
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5

TROPICAL CYCLONE 04B

Tropical Cyclone 04B was the second of two significant tropical cyclones to develop in the Bay of Bengal during November. This cyclone (Figure 3-04B-1) was one of the most intense to strike Bangladesh and eastern India in this century.

The formation of Tropical Cyclone 04B was preceded by a sustained surge of the northeast winter monsoon and low-level convergence across the Malay Peninsula. Beginning 19 November, prolonged, heavy rains occurred in northern Malaysia and southern Thailand. Flash flooding and mud-

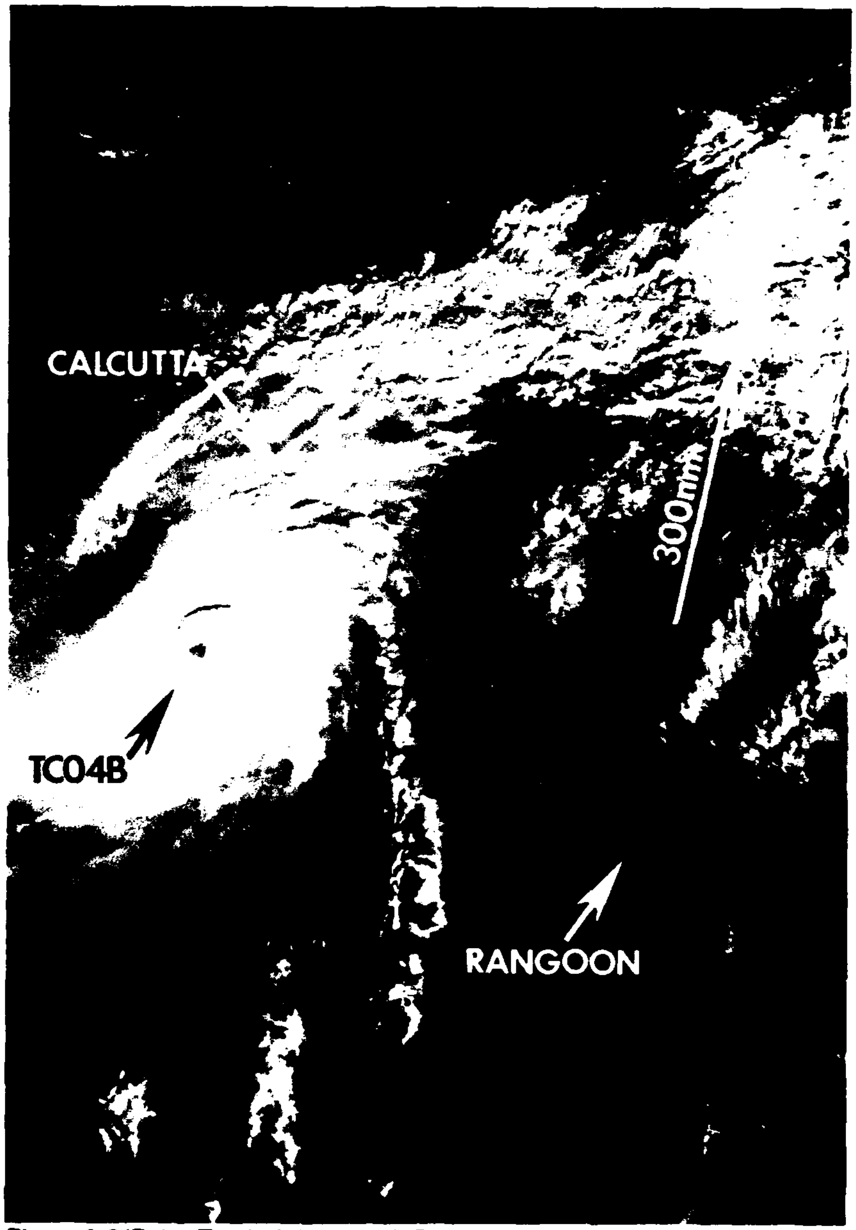
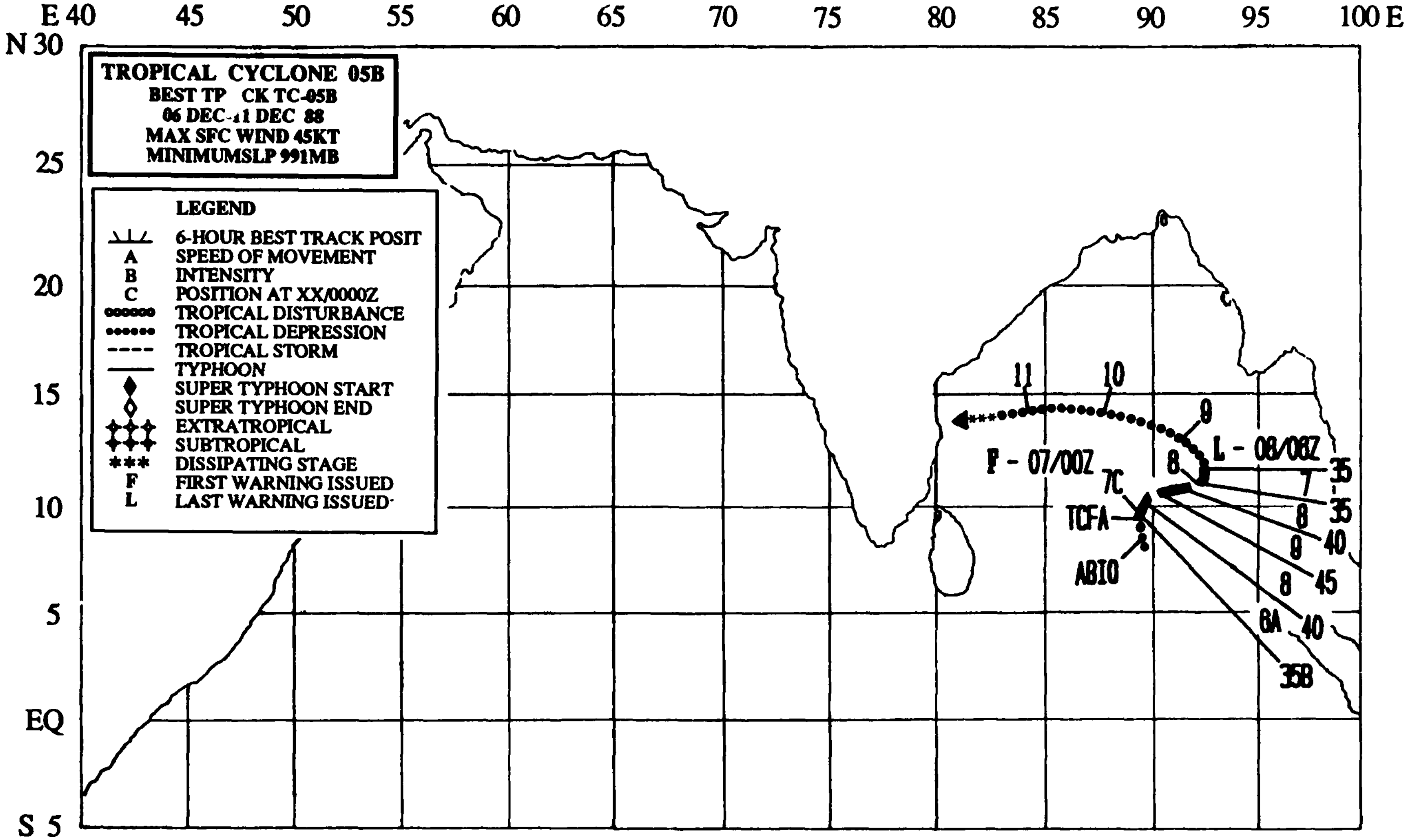


Figure 3-04B-1. Tropical Cyclone 04B approaching the coast with maximum sustained winds of over 100 kt (51 m/sec) (290251Z November DMSP visual imagery).

slides from deforested hillsides swept across low-lying villages, killing at least 1000 people and rendering another 100,000 homeless. At 211800Z, Tropical Cyclone 04B consolidated in the Straits of Malacca and was first mentioned on the Significant Tropical Weather Advisory. The central convection, organization and satellite intensity estimates quickly increased and a Tropical Cyclone Formation Alert was issued at 231830Z. The system tracked northwestward while remaining south of the subtropical ridge. The central convection continued to increase and organize, and the first warning followed at 240600Z.

Shortly after attaining typhoon intensity, at 260000Z, the system began tracking around the western periphery of the mid-level subtropical ridge. The ridge was broad, which allowed the tropical cyclone to move northward for three days prior to making landfall over the delta of the Ganges River. During this period Tropical Cyclone 04B gradually intensified, reaching a peak of 110 kt (57 m/sec) at the coast. As the cyclone swept inland, it ravaged the southern Bangladesh and northeastern India coastal zones, leaving at least 2000 people dead, 6000 missing and almost three million homeless. Up to seventy percent of the crops ready for harvest were destroyed. Bangladesh, which was attempting to recover from earlier flooding during the summer, in which 1500 lives were lost and countless were left homeless, was particularly hard hit.

Intentionally left blank.


TROPICAL CYCLONE 05B
BEST TP CK TC-05B
06 DEC-11 DEC 88
MAX SFC WIND 45KT
MINIMUMSLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
F - 07/00Z
L - 08/08Z
TCFA
ABIO
7C
11
10
9
8
35
7
35
8
40
9
45
8
40
6A
35B

TROPICAL CYCLONE 05B

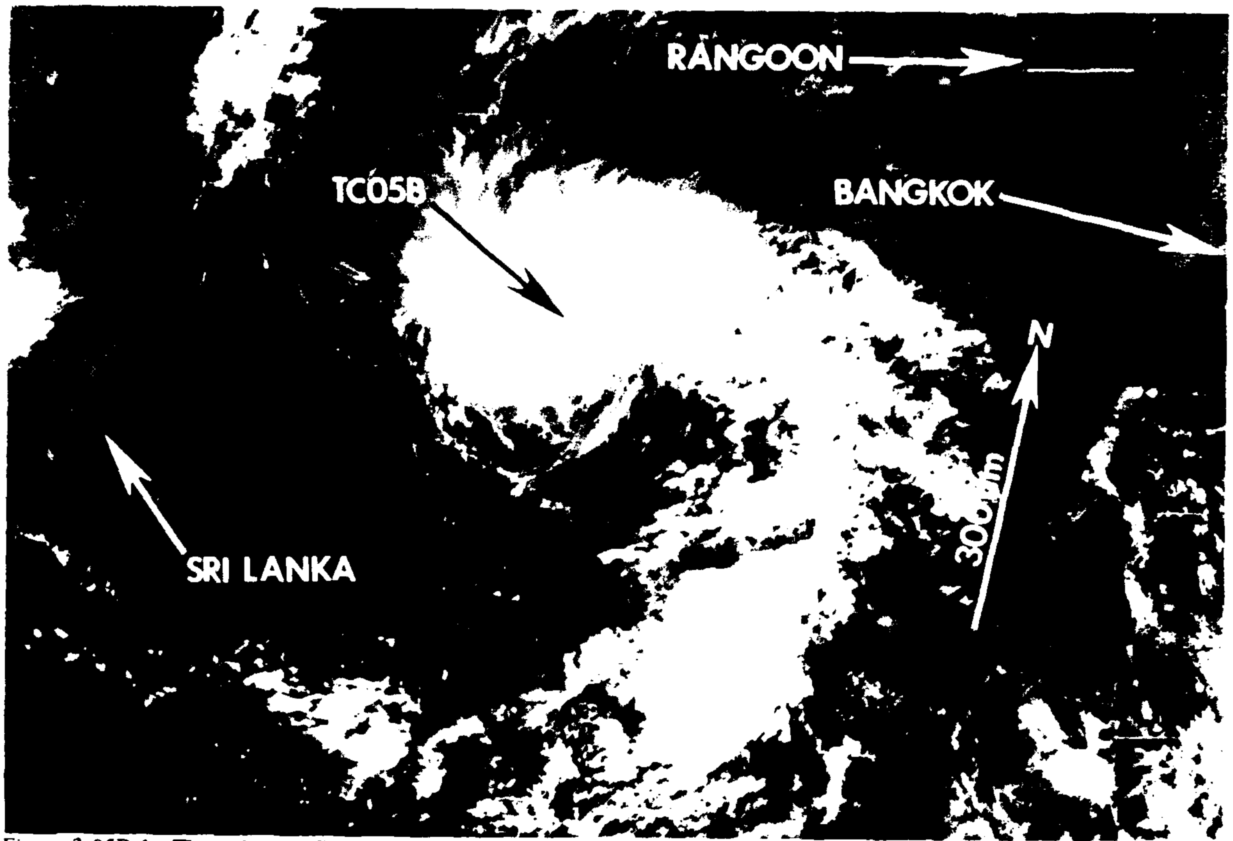


Figure 3-05B-1. The only significant tropical cyclone to form in the Bay of Bengal in December, Tropical Cyclone 05B was first detected as a poorly defined area of cloudiness in the southern Bay of Bengal. The Significant Tropical Weather Advisory was reissued at 061230Z to include the disturbance as suspect for further development. The cloud system continued to develop and a Tropical Cyclone Formation Alert was issued at 062100Z. The first warning followed at 070000Z, after satellite intensity analysis indicated 35 kt (18 m/sec) sustained surface winds. Once the peak intensity of 45 kt (23 m/sec) was reached, the tropical cyclone began to weaken and the final warning was issued at 080600Z. The remnants of Tropical Cyclone 05B persisted and struck off westward across the Bay of Bengal for three additional days, before dissipating along the east coast of India north of the city of Madras. The photo above shows Tropical Cyclone 05B shortly before peak intensity (070332Z December DMSP visual imagery).

Intentionally left blank.

CHAPTER IV - SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

1. GENERAL

The JTWC area of responsibility (AOR) was expanded on 1 October 1980 to include the southern hemisphere from 180° longitude westward to the east coast of Africa. Details on tropical cyclones in this region for July 1980 to June 1982 are contained in Diercks et. al. (1982). For the July 1982 through June 1984 period, reference the NOCC/JTWC TECH NOTE 86-1. As in earlier reports, data on tropical cyclones forming in, or moving into, the South Pacific Ocean east of 180° longitude (NWOC's AOR) are included for completeness. JTWC provides the numbers for all South Pacific and South Indian Ocean tropical cyclones. The current convention (as stated in USCINCPACINST 3140.1S) for labelling tropical cyclones that develop in the South Indian Ocean (west of 135° East longitude) is to add the suffix "S" to the assigned tropical cyclone number, while those originating in the South Pacific Ocean (east of 135° East longitude) receive a "P" suffix. The "P" suffix also applies to significant tropical cyclones which form east of 180° longitude in the South Pacific Ocean. Also, it should be noted that to encompass the southern hemisphere tropical cyclone season, which normally occurs from January through April, the limits of each southern hemisphere tropical cyclone year are defined as 1 July to 30 June. Thus, the 1988 southern hemisphere tropical cyclone year is from 1 July 1987 to 30 June 1988. This is in contrast to the labelling convention in the northern hemisphere, which is based on the calendar year (1 January to 31 December) to include the seasonal activity from May through December.

2. SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

Twenty-one significant tropical cyclones (Table 4-1 and Figure 4-1) occurred during the year (1 July 1987 through 30 June 1988) in the southern hemisphere AOR. This was lower than the twenty year average of 24.7 (Table 4-2) and significantly lower than the short term (1981-1985) average (Annual Tropical Cyclone Report, 1987) of 28.6. Five tropical cyclones occurred in the South Pacific Ocean, east of 165° East longitude, which is very close to the long-term mean (Table 4-3). The Australian area (105° to 165° East longitude) accounted for only two tropical cyclones, compared to the twenty year climatological mean of 10.3 cyclones. Fourteen tropical cyclones developed in the South Indian Ocean, which is almost six more than the twenty year mean of 8.4 cyclones.

Caveat: Intensity estimates for southern hemisphere tropical cyclones are derived primarily from evaluation of satellite imagery (Dvorak, 1984) and from intensity estimates reported by other regional centers. Only in isolated cases are intensity estimates based on conventional surface observations. Estimates of minimum sea-level pressure are usually derived from the Atkinson and Holliday (1977) relationship between maximum sustained one-minute surface wind and minimum sea-level pressure (Table 4-4). This relationship has been shown to be representative for tropical cyclones in the western North Pacific and is also used by Australian region warning agencies to provide intensity estimates. However, these pressure estimates are usually based on wind intensities derived from interpretation of satellite imagery. Considerable caution should be exercised when using resultant pressure values in future tropical cyclone work.

TABLE 4-1

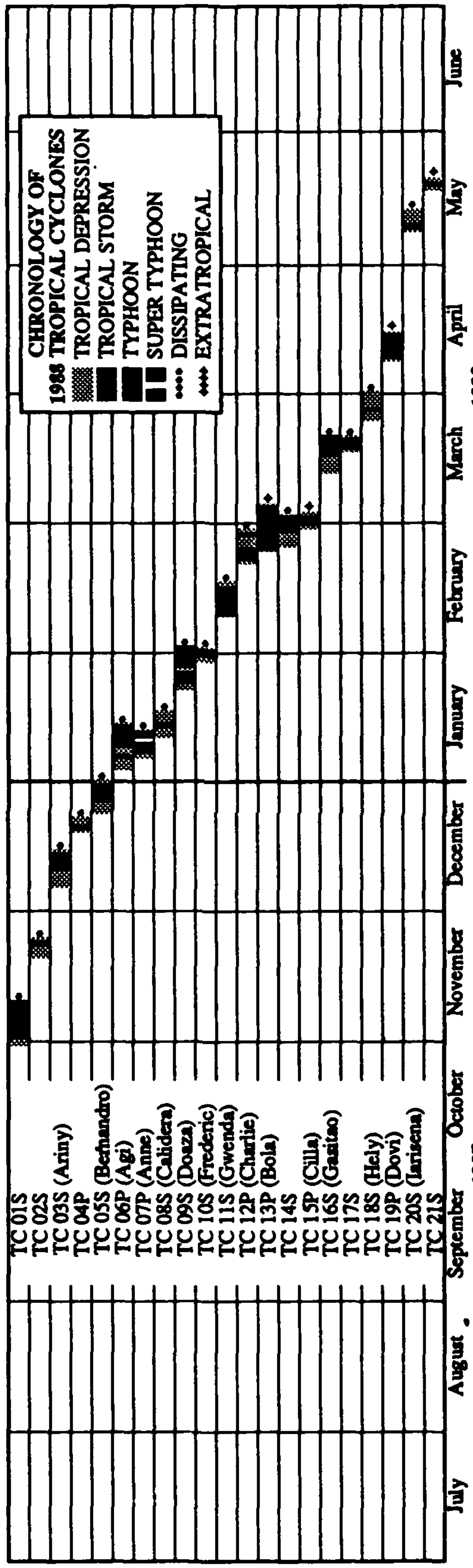
SOUTH PACIFIC AND SOUTH INDIAN OCEANS
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP-MB
01S - - - -	01 NOV - 09 NOV	20	55 (28)	984
02S - - - -	24 NOV - 26 NOV	5	40 (21)	994
03S ARINY	09 DEC - 14 DEC	10	55 (28)	984
04P - - - -	22 DEC - 23 DEC	3	35 (18)	997
05S BERNANDRO	27 DEC - 01 JAN	11	35 (18)	997
06P AGI	06 JAN - 07 JAN	3	35 (18)	997
06P AGI *	09 JAN - 14 JAN	13	70 (36)	972
07P ANNE	07 JAN - 14 JAN	14	140 (72)	898
08S CALIDERA	13 JAN - 15 JAN	5	65 (33)	976
09S DOAZA	23 JAN - 26 JAN	7	55 (28)	984
09S DOAZA *	28 JAN - 02 FEB	11	115 (59)	927
10S FREDERIC	31 JAN - 02 FEB	6	65 (33)	976
11S GWENDA **	08 FEB - 16 FEB	16	90 (46)	954
12P CHARLIE	21 FEB - 24 FEB	9	45 (23)	991
12P CHARLIE *	28 FEB - 29 FEB	3	35 (18)	997
13P BOLA	24 FEB - 04 MAR	20	105 (54)	935
14S - - - -	27 FEB - 02 MAR	8	85 (44)	958
15P CILLA	28 FEB - 03 MAR	8	45 (23)	991
16S GASITAO	16 MAR - 23 MAR	16	130 (67)	910
17S - - - -	17 MAR - 20 MAR	7	45 (23)	991
18S HELY	27 MAR - 28 MAR	3	40 (21)	994
19P DOVI	09 APR - 15 APR	12	70 (36)	972
20S IARISENA	09 MAY - 10 MAY	3	40 (21)	994
21S - - - -	19 MAY - 20 MAY	4	35 (18)	995
	TOTAL	217		

* REGENERATED
** ALSO NAMED EZENINA

NOTE: NAMES OF SOUTHERN HEMISPHERE TROPICAL CYCLONES ARE GIVEN BY THE REGIONAL WARNING CENTERS (NANDI, BRISBANE, DARWIN, PERTH AND MAURITIUS) AND ARE APPENDED TO JTWC WARNINGS, WHEN AVAILABLE.

Figure 4-1



1988 CHRONOLOGY OF TROPICAL CYCLONES
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON
DISSIPATING
EXTRATROPICAL
TC 01S
TC 02S
TC 03S (Ariny)
TC 04P
TC 05S (Bethandro)
TC 06P (Agi)
TC 07P (Anne)
TC 08S (Calidera)
TC 09S (Doaza)
TC 10S (Frederic)
TC 11S (Gwenda)
TC 12P (Charlie)
TC 13P (Bola)
TC 14S
TC 15P (Cilla)
TC 16S (Gasitao)
TC 17S
TC 18S (Hely)
TC 19P (Dovi)
TC 20S (Iarisena)
TC 21S
July
August
September
October
1987
November
December
January
February
March
1988
April
May
June

TABLE 4-2

FREQUENCY OF TROPICAL CYCLONES BY MONTH AND YEAR
SOUTH PACIFIC AND SOUTH INDIAN OCEANS

YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
(1959-1978) AVERAGE*	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
(1981-1988) AVERAGE	0.4	0.1	0.1	0.5	1.5	3.4	6.8	7.0	3.8	3.1	0.9	0.1	27.7
TOTAL CASES	3	1	1	4	12	27	54	56	30	25	7	1	221

* (GRAY, 1979)

TABLE 4-3

ANNUAL VARIATION OF SOUTHERN HEMISPHERE
TROPICAL CYCLONES BY OCEAN BASIN

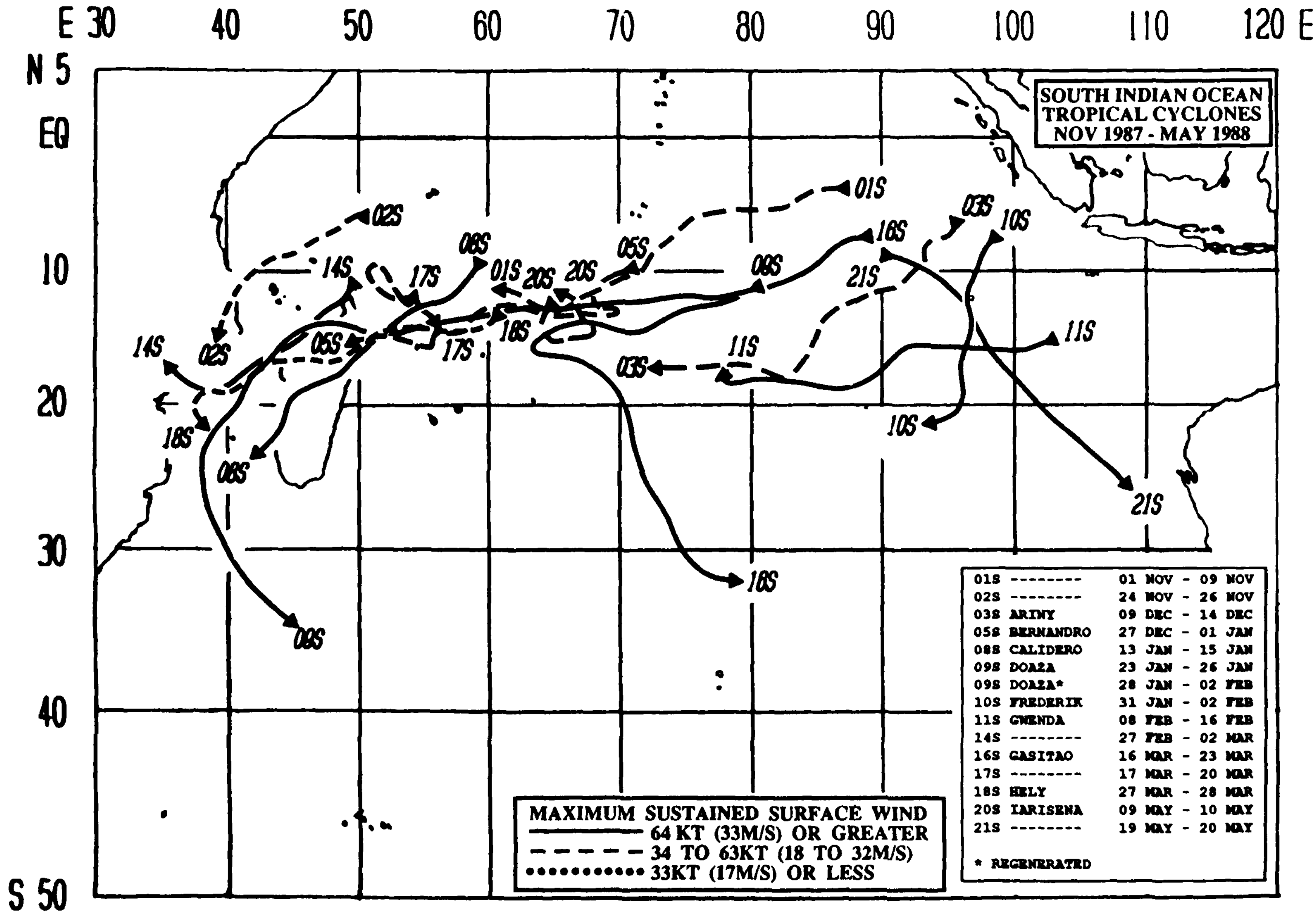
YEAR	SOUTH INDIAN (WEST OF 105° E)	AUSTRALIAN (105° E - 165° E)	SOUTH PACIFIC (EAST OF 165° E)	TOTAL
(1959-1978) AVERAGE*	8.4	10.3	5.9	24.7
1981	13	8	3	24
1982	12	11	2	25
1983	7	6	12	25
1984	14	14	2	30
1985	14	15	6	35
1986	14	16	3	33
1987	9	8	11	28
1988	14	2	5	21
(1981-1988) AVERAGE	12.1	10.0	5.5	27.6
TOTAL CASES	97	80	44	221

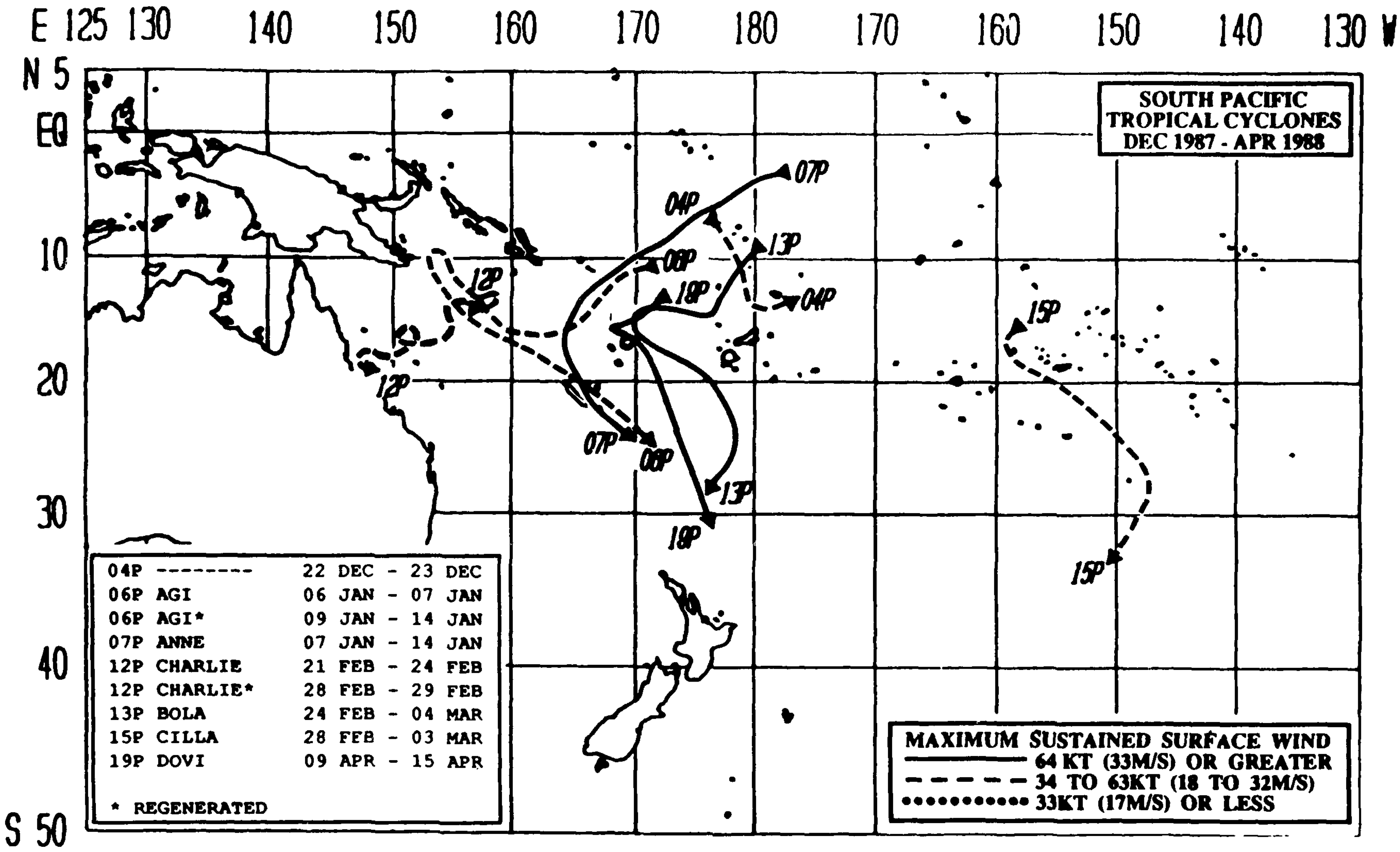
* (GRAY, 1979)

TABLE 4-4

MAXIMUM SUSTAINED SURFACE WINDS AND EQUIVALENT MINIMUM SEA-LEVEL PRESSURE (ATKINSON AND HOLLIDAY, 1977)

MAXIMUM SUSTAINED SURFACE WIND (KT)	MINIMUM SEA-LEVEL PRESSURE (MB)
30	1000
35	997
40	994
45	991
50	987
55	984
60	980
65	976
70	972
75	967
80	963
85	958
90	954
95	948
100	943
105	938
110	933
115	927
120	922
125	916
130	910
135	906
140	898
145	892
150	885
155	879
160	872
165	865
170	858


SOUTH INDIAN OCEAN
TROPICAL CYCLONES
NOV 1987 - MAY 1988
E 30
40
50
60
70
80
90
100
110
120 E
N 5
EQ
10
20
30
40
S 50
01S --------- 01 NOV - 09 NOV
02S --------- 24 NOV - 26 NOV
03S ARINY 09 DEC - 14 DEC
05S BERNANDRO 27 DEC - 01 JAN
08S CALIDERO 13 JAN - 15 JAN
09S DOAZA 23 JAN - 26 JAN
09S DOAZA* 28 JAN - 02 FEB
10S FREDERIK 31 JAN - 02 FEB
11S GWENDA 08 FEB - 16 FEB
14S --------- 27 FEB - 02 MAR
16S GASITAO 16 MAR - 23 MAR
17S --------- 17 MAR - 20 MAR
18S HELY 27 MAR - 28 MAR
20S IARISENA 09 MAY - 10 MAY
21S --------- 19 MAY - 20 MAY
* REGENERATED
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS


SOUTH PACIFIC
TROPICAL CYCLONES
DEC 1987 - APR 1988
E 125 130 140 150 160 170 180 170 160 150 140 130 W
N 5
EQ
10
20
30
40
S 50
04P -------- 22 DEC - 23 DEC
06P AGI 06 JAN - 07 JAN
06P AGI* 09 JAN - 14 JAN
07P ANNE 07 JAN - 14 JAN
12P CHARLIE 21 FEB - 24 FEB
12P CHARLIE* 28 FEB - 29 FEB
13P BOLA 24 FEB - 04 MAR
15P CILLA 28 FEB - 03 MAR
19P DOVI 09 APR - 15 APR
* REGENERATED
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
07P
04P
13P
06P
18P
04P
12P
12P
07P
06P
13P
18P
15P
15P

Intentionally left blank.

CHAPTER V - SUMMARY OF FORECAST VERIFICATION

1. ANNUAL FORECAST VERIFICATION

a. WESTERN NORTH PACIFIC OCEAN

Verification of warnings at initial, 24-, 48- and 72-hour forecast positions was made against the final best track. The (scalar) forecast, along-track and cross-track errors (illustrated in Figure 5-1) were then calculated for each tropical cyclone and are presented in Tables 5-1A, 5-1B, 5-1C and 5-1D, as appropriate. The frequency distributions of forecast errors in 30 nm (56 km) increments for 24-, 48-, and 72-hour forecasts are in Figures 5-2A through 5-2C, respectively. A summation of the mean forecast errors, since 1971, is shown in Table 5-2A. Table 5-2B includes mean along-track and cross-track forecast errors for 1988. A comparison of the annual mean forecast errors for all tropical cyclones as compared to those tropical cyclones that reached typhoon intensity can be seen in Table 5-3. The mean forecast errors for 1988 as compared to the nineteen previous years are graphed in Figure 5-3.

b. NORTH INDIAN OCEAN

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the North Indian Ocean by the same methods used for the western North Pacific. These error statistics should not be taken as representative of any trend due to the small sample number. Table 5-4 is the initial and forecast along-track and cross-track error summary for the North Indian Ocean. Table 5-5A contains a summary of the annual mean forecast errors for each year. Table 5-5B includes along-track and cross-track errors for 1988. Forecast errors are plotted in Figure 5-4 (Seventy-two hour forecast errors were evaluated for the first time in 1979). There were no verifying 72-hour forecast in 1983 and 1985.

c. SOUTH PACIFIC AND SOUTH INDIAN OCEANS

The positions given for warning times and those at the 24-, 48-, and 72-hour valid times were verified for tropical cyclones in the Southern Hemisphere by the same methods used for the western North Pacific. It should be noted that due to the lack of verifying ground-truth data, these error statistics should not be taken as representative of any trend. Table 5-6A is the initial, forecast along-track and cross-track error summary for the southern hemisphere. Table 5-6B has the number of warnings verified at each forecast period. Table 5-7A contains a summary of the annual mean forecast errors for each year. Table 5-7B includes along- and cross-track errors for 1988. Forecast errors are plotted in Figure 5-5.

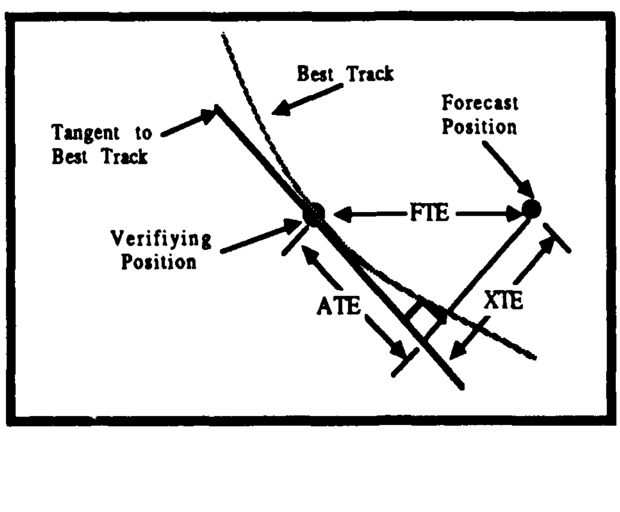


Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

TABLE 5-1A

INITIAL POSITION ERROR SUMMARY
WESTERN NORTH PACIFIC OCEAN
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		ERROR (NM)	SAMPLE SIZE
(01W)	TY ROY	13	41
(02W)	TY SUSAN	18	17
(03W)	TD 03W	19	6
(04W)	TY THAD	24	20
(05W)	TS VANESSA	27	11
(06W)	TY WARREN	19	30
(07W)	TS AGNES	33	8
(08W)	TS BILL	12	5
(09W)	TS CLARA	24	6
(10W)	TY DOYLE	14	24
(11W)	TS ELSIE	28	6
(11W)	TS ELSIE*	27	4
(12W)	TY FABIAN	21	18
(13W)	TS GAY	33	6
(14W)	TY HAL	18	37
(01C)	TY ULEKI	17	21
(15W)	TS IRMA	17	16
(16W)	TS JEFF	15	9
(17W)	TS KIT	26	12
(18W)	TS LEE	21	15
(19W)	TS MAMIE	36	4
(20W)	STY NELSON	10	30
(21W)	TY ODESSA	16	22
(22W)	TY PAT	17	17
(23W)	TY RUBY	24	30
(24W)	TY SKIP	18	30
(25W)	TY TESS	14	10
(26W)	TS VAL	57	10
TOTALS		23	465

* REGENERATED

TABLE 5-1B

SUMMARY OF 24-HOUR FORECAST ERRORS
WESTERN NORTH PACIFIC OCEAN
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TY ROY	123	104	-28	47	13	37
(02W)	TY SUSAN	146	100	-85	85	-32	13
(03W)	TD 03W	169	127	**	104	**	4
(04W)	TY THAD	143	103	-95	90	-49	16
(05W)	TS VANESSA	194	180	**	54	**	7
(06W)	TY WARREN	86	61	-25	46	24	28
(07W)	TS AGNES	322	271	**	134	**	5
(08W)	TS BILL	119	106	**	52	**	3
(09W)	TS CLARA	89	36	**	79	**	3
(10W)	TY DOYLE	106	82	-50	61	-50	20
(11W)	TS ELSIE	283	250	**	104	**	2
R(11W)	TS ELSIE	129	127	**	19	**	2
(12W)	TY FABIAN	141	94	-46	77	9	14
(13W)	TS GAY	98	64	**	66	**	3
(14W)	TY HAL	122	89	-76	61	-16	33
(01C)	TY ULEKI	82	47	4	58	24	19
(15W)	TS IRMA	76	42	11	54	-1	14
(16W)	TS JEFF	64	47	**	34	**	5
(17W)	TS KIT	96	58	**	63	**	8
(18W)	TS LEE	127	110	-101	41	-29	11
(19W)	TS MAMIE	***	***	***	***	***	0
(20W)	STY NELSON	64	45	-11	34	-11	26
(21W)	TY ODESSA	100	56	-52	75	-29	18
(22W)	TY PAT	140	110	-110	60	37	13
(23W)	TY RUBY	109	82	-17	53	0	26
(24W)	TY SKIP	99	85	-5	41	7	29
(25W)	TY TESS	57	49	**	24	**	8
(26W)	TS VAL	228	152	**	146	**	6
TOTALS		114	85	-45	58	-9	373

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.
R = REGENERATED

1. THE MEAN IS THE SUM OF ALL THE VALUES DIVIDED BY THE NUMBER OF OBSERVATIONS.
2. THE MEDIAN IS THE MIDDLE VALUE OF THE SAMPLE.
3. THE ALONG-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED AHEAD OR BEHIND THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE BEHIND TRACK OR SLOW, AND POSITIVE VALUES WERE AHEAD OF TRACK OR FAST).
4. THE CROSS-TRACK ERROR COMPONENT IS HOW FAR THE WARNING POSITION WAS DISPLACED TO THE LEFT OR RIGHT OF THE BEST TRACK POSITION. THE SAMPLE CONSISTS OF TWO PARTS: THE MEAN (DISTANCE) AND THE MEDIAN (NEGATIVE VALUES WERE LEFT OF TRACK AND POSITIVE VALUES WERE RIGHT OF TRACK).

TABLE 5-1C

SUMMARY OF 48-HOUR FORECAST ERRORS
WESTERN NORTH PACIFIC OCEAN
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W)	TY ROY	246	196	-62	119	22	33
(02W)	TY SUSAN	378	344	**	106	**	9
(03W)	TD 03W	***	***	***	***	***	0
(04W)	TY THAD	274	233	-223	123	-81	12
(05W)	TS VANESSA	386	352	**	158	**	3
(06W)	TY WARREN	152	118	-52	74	56	23
(07W)	TS AGNES	714	706	**	108	**	1
(08W)	TS BILL	***	***	***	***	***	0
(09W)	TS CLARA	***	***	***	***	***	0
(10W)	TY DOYLE	316	258	-173	155	-173	16
(11W)	TS ELSIE	***	***	***	***	***	0
R(11W)	TS ELSIE	***	***	***	***	***	0
(12W)	TY FABIAN	177	108	**	124	**	10
(13W)	TS GAY	***	***	***	***	***	0
(14W)	TY HAL	249	194	-122	130	-71	29
(01C)	TY ULEKI	146	92	49	94	42	15
(15W)	TS IRMA	94	76	**	45	**	10
(16W)	TS JEFF	103	91	**	48	**	1
(17W)	TS KIT	120	68	**	98	**	4
(18W)	TS LEE	221	186	**	89	**	7
(19W)	TS MAMIE	***	***	***	***	***	0
(20W)	STY NELSON	128	88	8	70	-48	22
(21W)	TY ODESSA	245	217	**	109	**	10
(22W)	TY PAT	303	269	**	110	**	9
(23W)	TY RUBY	162	121	-90	75	13	22
(24W)	TY SKIP	199	164	-84	85	53	21
(25W)	TY TESS	123	109	**	53	**	4
(26W)	TS VAL	768	75	**	764	**	1
TOTALS		216	170	-100	103	-14	262

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** FORECASTS WERE NOT ISSUED OR DID NOT VERIFY.
R = REGENERATED

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

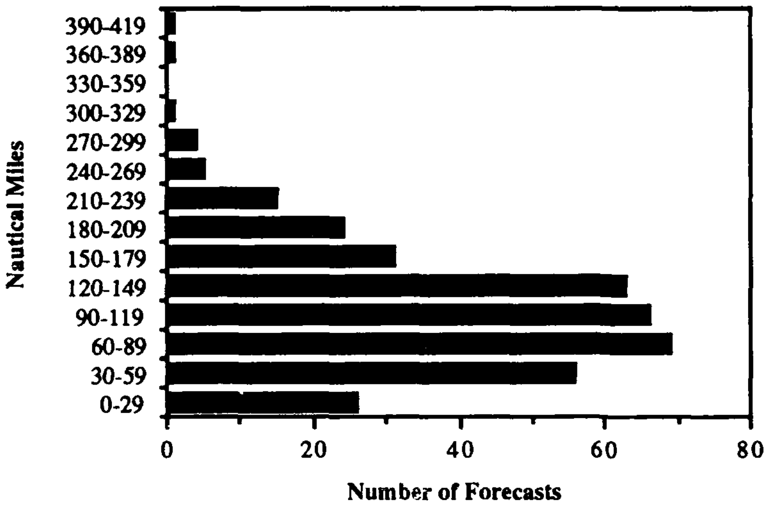
TABLE 5-1D

SUMMARY OF 72-HOUR FORECAST ERRORS
WESTERN NORTH PACIFIC OCEAN
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	FORECAST ERROR (NM)	ALONG-TRACK ERROR MEAN*	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN*	CROSS-TRACK ERROR MEDIAN	SAMPLE SIZE
(01W) TY ROY	401	313	-150	202	77	29
(02W) TY SUSAN	423	385	**	121	**	5
(03W) TD 03W	***	***	***	***	***	0
(04W) TY THAD	329	315	**	75	**	8
(05W) TS VANESSA	***	***	***	***	***	0
(06W) TY WARREN	246	193	-106	113	96	16
(07W) TS AGNES	***	***	***	***	***	0
(08W) TS BILL	***	***	***	***	***	0
(09W) TS CLARA	***	***	***	***	***	0
(10W) TY DOYLE	626	516	-517	297	-517	11
(11W) TS ELSIE	***	***	***	***	***	0
R(11W) TS ELSIE	***	***	***	***	***	0
(12W) TY FABIAN	279	256	**	91	**	6
(13W) TS GAY	***	***	***	***	***	0
(14W) TY HAL	355	298	-124	151	-104	25
(01C) TY ULEKI	153	80	78	120	39	11
(15W) TS IRMA	158	39	**	135	**	6
(16W) TS JEFF	***	***	***	***	***	0
(17W) TS KIT	***	***	***	***	***	0
(18W) TS LEE	265	236	**	104	**	3
(19W) TS MAMIE	***	***	***	***	***	0
(20W) STY NELSON	148	92	15	103	-79	18
(21W) TY ODESSA	686	544	**	398	**	5
(22W) TY PAT	436	366	**	235	**	5
(23W) TY RUBY	210	112	-105	156	28	18
(24W) TY SKIP	260	202	-194	143	138	17
(25W) TY TESS	***	***	***	***	***	0
(26W) TS VAL	***	***	***	***	***	0
TOTALS	315	244	-159	159	-11	183

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** NOT ENOUGH WARNINGS WERE ISSUED TO VERIFY THE FORECAST.
R = REGENERATED

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.



24-HOUR
FORECAST ERRORS (NM)

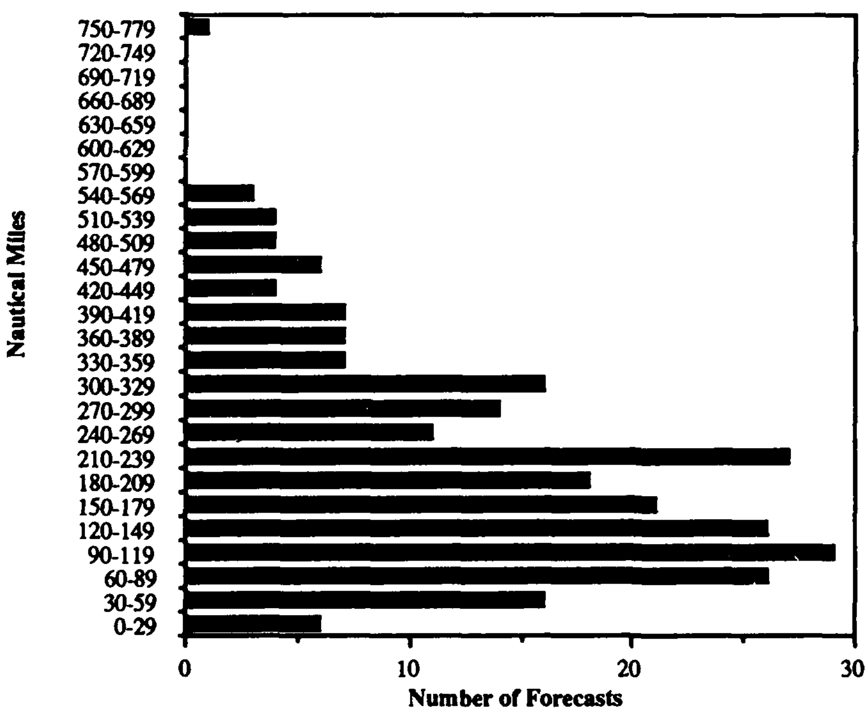
MEAN: **114**

MEDIAN: **113**

STANDARD DEVIATION: **73**

CASES: **373**

Figure 5-2A. Frequency distribution of the 24-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.



48-HOUR
FORECAST ERRORS (NM)

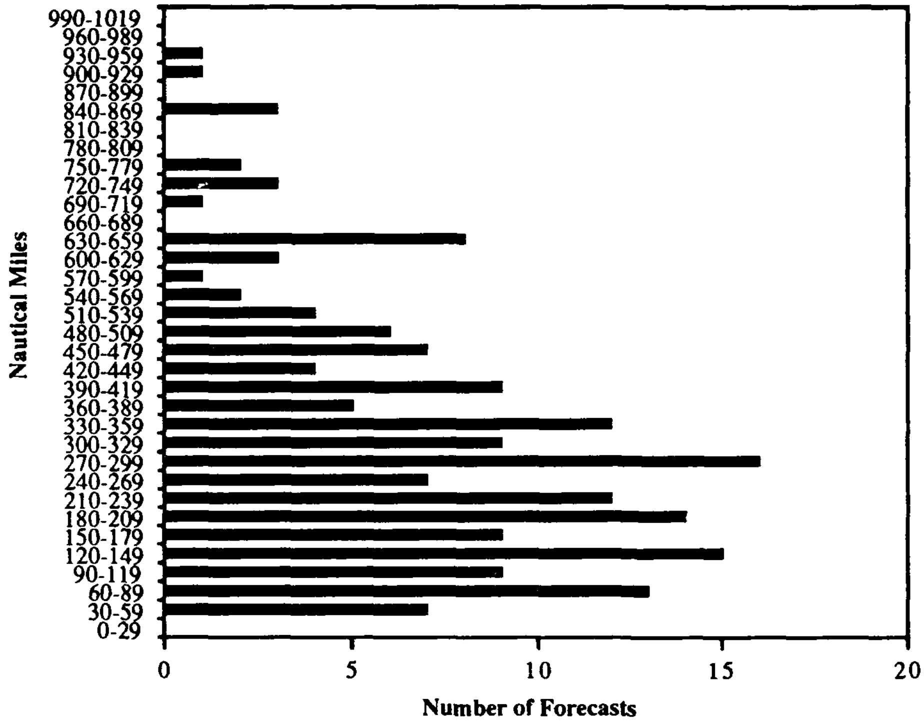
MEAN: **216**

MEDIAN: **212**

STANDARD DEVIATION: **139**

CASES: **262**

Figure 5-2B. Frequency distribution of the 48-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.



72-HOUR FORECAST ERRORS (NM)

MEAN: **315**

MEDIAN: **309**

STANDARD DEVIATION: **202**

CASES: **183**

Figure 5-2C. Frequency distribution of the 72-hour forecast errors in 30 nm (56 km) increments for all significant tropical cyclones in the western North Pacific during 1988.

TABLE 5-2A

ANNUAL MEAN FORECAST ERRORS FOR THE WESTERN NORTH PACIFIC

	24-HOUR		48-HOUR		72-HOUR	
YEAR	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE
1971	111	64	212	118	317	117
1972	117	72	245	146	381	210
1973	108	74	197	134	253	162
1974	120	78	226	157	348	245
1975	138	84	288	181	450	290
1976	117	71	230	132	338	202
1977	148	83	283	157	407	228
1978	127	75	271	179	410	297
1979	124	77	226	151	316	223
1980	126	79	243	164	389	287
1981*	123	75	220	119	334	168
1982*	113	67	237	139	341	206
1983*	117	72	259	132	405	237
1984*	117	66	233	137	363	231
1985*	117	66	231	134	367	214
1986	121	**	261	**	394	**
1987	107	**	204	**	303	**
1988	114	**	216	**	315	**

* THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981. THEREFORE, A DIRECT COMPARISON IN RIGHT-ANGLE ERROR STATISTICS CANNOT BE MADE BETWEEN ERRORS COMPUTED BEFORE 1981 AND THOSE COMPUTED SINCE 1981.

** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. (SEE FIGURE 5-1B FOR THE DEFINITION OF CROSS-TRACK ERROR).

TABLE 5-2B

1988 MEAN FORECAST, ALONG-TRACK AND CROSS-TRACK ERRORS FOR THE WESTERN NORTH PACIFIC OCEAN (ERRORS IN NM)

FORECAST	FORECAST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
24-HOUR	114	85	-45	58	-9
48-HOUR	216	170	-100	103	-14
72-HOUR	315	244	-159	159	-11

TABLE 5-3

ANNUAL MEAN FORECAST ERRORS (NM) WESTERN NORTH PACIFIC

YEAR	24-HOUR ALL	24-HOUR TYPHOONS*	48-HOUR ALL	48-HOUR TYPHOONS*	72-HOUR ALL	72-HOUR TYPHOONS*
1959		117**		267**		
1960		177**		354**		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327

* FORECASTS WERE VERIFIED WHEN THE TROPICAL CYCLONE INTENSITIES WERE OVER 35 KT (18 M/SEC).

** FORECAST POSITIONS NORTH OF 35 DEGREES NORTH LATITUDE WERE NOT VERIFIED.

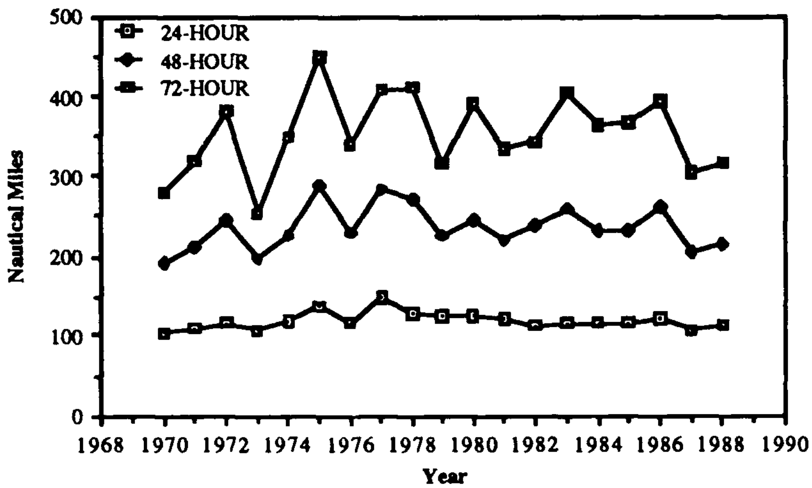


Figure 5-3. Annual mean forecast errors (nm) for all significant tropical cyclones in the western North Pacific.

TABLE 5-4

FORECAST ERROR SUMMARY FOR THE NORTH INDIAN OCEAN
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	INITIAL POSITION ERROR (NM)	NUMBER OF WARNINGS
TC 01A	61	10
TC 02B	30	3
TC 03B	28	3
TC 04B	22	22
TC 05B	37	6

24-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
TC 01A	188	172	**	58	**
TC 02B	--	--	--	--	--
TC 03B	--	--	--	--	--
TC 04B	90	64	-55	48	-10
TC 05B	171	92	**	143	**

18-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
TC 01A	484	155	**	456	**
TC 02B	--	--	--	--	--
TC 03B	--	--	--	--	--
TC 04B	186	107	-62	141	-100
TC 05B	--	--	--	--	--

72-HOUR FORECASTS

TROPICAL CYCLONE	FCST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
TC 01A	--	--	--	--	--
TC 02B	--	--	--	--	--
TC 03B	--	--	--	--	--
TC 04B	409	227	-213	303	-306
TC 05B	--	--		--	--

** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.

TABLE 5-5A

ANNUAL MEAN FORECAST ERRORS FOR THE NORTH INDIAN OCEAN

YEAR	24-HOUR FORECAST	24-HOUR RIGHT-ANGLE	48-HOUR FORECAST	48-HOUR RIGHT-ANGLE	72-HOUR FORECAST	72-HOUR RIGHT-ANGLE
1971*	232	---	410	---	---	---
1972*	224	101	292	112	---	---
1973*	182	99	299	160	---	---
1974*	137	81	238	146	---	---
1975	145	99	228	144	---	---
1976	138	108	204	159	---	---
1977	122	94	292	214	---	---
1978	133	86	202	128	---	---
1979	151	99	270	202	437	371
1980	115	73	93	87	167	126
1981**	109	65	176	103	197	73
1982**	138	66	368	175	762	404
1983**	117	46	153	67	---	---
1984**	154	71	274	127	388	159
1985**	123	51	242	109	---	---
1986	134	***	168	***	269	***
1987	144	***	205	***	305	***
1988	120	***	219	***	409	***

* THE WESTERN BAY OF BENGAL AND ARABIAN SEA WERE NOT INCLUDED IN THE JTWC AREA OF RESPONSIBILITY UNTIL THE 1975 TROPICAL CYCLONE SEASON.

** THE TECHNIQUE FOR CALCULATING RIGHT-ANGLE ERROR WAS REVISED IN 1981. THEREFORE, A DIRECT COMPARISON IN RIGHT-ANGLE ERROR STATISTICS CANNOT BE MADE BETWEEN ERRORS COMPUTED BEFORE 1981 AND THOSE COMPUTED SINCE 1981.

*** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. (SEE TABLE 5-1B FOR THE DEFINITION OF CROSS-TRACK ERROR).

TABLE 5-5B

1988 MEAN FORECAST,
ALONG-TRACK AND CROSS-TRACK ERRORS (NM)
NORTH INDIAN OCEAN

TIME	FORECAST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
24-HOUR	120	89	-68	63	-34
48-HOUR	219	112	-39	176	-142
72-HOUR	409	227	-213	303	-306

SEE TABLE 5-1B FOR EXPLANATIONS OF ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

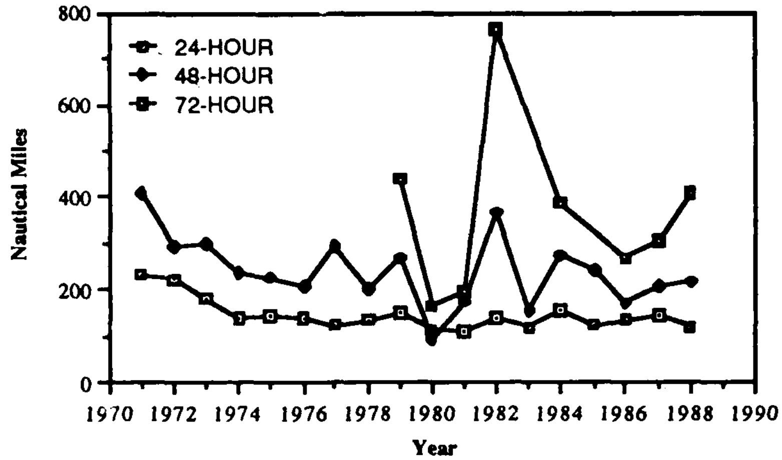


Figure 5-4. Annual mean forecast errors (nm) for all significant tropical cyclones in the North Indian Ocean.

TABLE 5-6A

FORECAST ERROR SUMMARY (ERRORS IN NM)
SOUTH PACIFIC AND SOUTH INDIAN OCEANS
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	INITIAL POSIT ERROR	24-HR FCST ERROR	24-HOUR ALONG-TRACK MEAN*	24-HOUR ALONG-TRACK MEDIAN	24-HOUR CROSS-TRACK MEAN*	24-HOUR CROSS-TRACK MEDIAN	48-HR FCST ERROR	48-HOUR ALONG-TRACK MEAN*	48-HOUR ALONG-TRACK MEDIAN	48-HOUR CROSS-TRACK MEAN*	48-HOUR CROSS-TRACK MEDIAN
TC 01S	33	125	56	9	98	24	216	148	84	137	71
TC 02S	21	57	54	**	18	**	***	***	***	***	***
TC 03S	34	126	88	**	73	**	273	176	**	164	**
TC 04P	58	***	***	***	***	***	***	***	***	***	***
TC 05S	39	158	125	**	81	**	517	507	**	98	**
TC 06P	63	242	212	-212	94	50	433	364	**	193	**
TC 07P	25	113	59	-6	78	-28	198	112	**	139	**
TC 08S	16	63	58	**	13	**	75	60	**	41	**
TC 09S	37	115	76	-68	59	-12	233	166	**	115	**
TC 10S	25	179	92	**	140	**	430	390	**	161	**
TC 11S	26	133	89	-22	79	-31	283	182	-41	193	-42
TC 12P	79	206	109	**	55	**	234	183	**	132	**
TC 13P	26	157	122	-89	102	31	337	190	-66	251	19
TC 14S	21	111	77	**	67	**	269	184	**	153	**
TC 15P	58	158	121	**	77	**	558	487	**	222	**
TC 16S	32	168	117	-50	112	-10	299	188	-56	185	4
TC 17S	21	205	108	**	166	**	375	301	**	160	**
TC 18S	20	***	***	***	***	***	***	***	***	***	***
TC 19P	22	118	95	**	51	**	292	275	**	84	**
TC 20S	18	139	11	**	139	**	277	276	**	17	**
TC 21S	33	207	191	**	66	**	***	***	***	***	***
AVERAGES	34	146	98	-63	83	3	290	246	-20	144	13

* THE MEAN WAS COMPUTED FROM ABSOLUTE VALUES.
** THE MEDIAN WAS NOT COMPUTED FOR INSTANCES OF TEN CASES OR LESS.
*** NOT ENOUGH WARNINGS WERE ISSUED TO VERIFY THE FORECAST.

SEE TABLE 5-1B FOR EXPLANATIONS OF THE TERMS MEAN, MEDIAN, ALONG-TRACK ERROR AND CROSS-TRACK ERROR.

TABLE 5-6B

SOUTH PACIFIC AND SOUTH INDIAN OCEANS
NUMBER OF WARNINGS

TROPICAL CYCLONE		INITIAL POSITION	24-HOUR FORECAST	48-HOUR FORECAST
TC-01S	-----	20	18	15
TC-02S	-----	5	1	0
TC-03S	ARINY	10	7	6
TC-04P	-----	2	0	0
TC-05S	BERNANDRO	11	9	1
TC-06P	AGI	3	1	0
TC-06P	AGI*	12	5	2
TC-07P	ANNE	14	6	3
TC-08S	CALIDERA	5	2	1
TC-09S	DOAZA	7	3	1
TC-09S	DOAZA*	11	5	2
TC-10S	FREDERIC	6	2	1
TC-11S	GWENDA**	16	7	3
TC-12P	CHARLIE	9	3	2
TC-12P	CHARLIE*	3	0	0
TC-13P	BOLA	20	9	4
TC-14S	-----	6	3	1
TC-15P	CILLA***	6	2	1
TC-16S	GASITAO	16	7	3
TC-17S	-----	7	3	1
TC-18S	HELY	3	1	0
TC-19P	DOVI	12	5	2
TC-20S	IARISENA	3	1	0
TC-21S	-----	3	1	0
TOTALS		210	101	49

* REGENERATED
** ALSO NAMED EZENINA
*** NWOC SYSTEM

TABLE 5-7A

ANNUAL MEAN FORECAST ERRORS (NM)
SOUTH PACIFIC AND SOUTH INDIAN OCEANS

	24-HOUR		48-HOUR	
YEAR	FORECAST	RIGHT-ANGLE	FORECAST	RIGHT-ANGLE
1981	165	119	315	216
1982	144	91	274	174
1983	154	84	288	150
1984	133	73	231	124
1985	138	78	242	133
1986	133	**	268	**
1987	145	**	280	**
1988	146	**	290	**

** IN 1986, RIGHT-ANGLE ERROR WAS REPLACED BY CROSS-TRACK ERROR. SEE TABLE 5-1B FOR AN EXPLANATION OF CROSS-TRACK ERROR.

TABLE 5-7B

**1988 MEAN FORECAST,
ALONG-TRACK AND CROSS-TRACK ERRORS (NM)
SOUTH PACIFIC AND SOUTH INDIAN OCEANS**

TIME	FORECAST ERROR	ALONG-TRACK ERROR MEAN	ALONG-TRACK ERROR MEDIAN	CROSS-TRACK ERROR MEAN	CROSS-TRACK ERROR MEDIAN
24-HOUR	146	101	-62	86	-1
48-HOUR	290	203	-100	166	-25

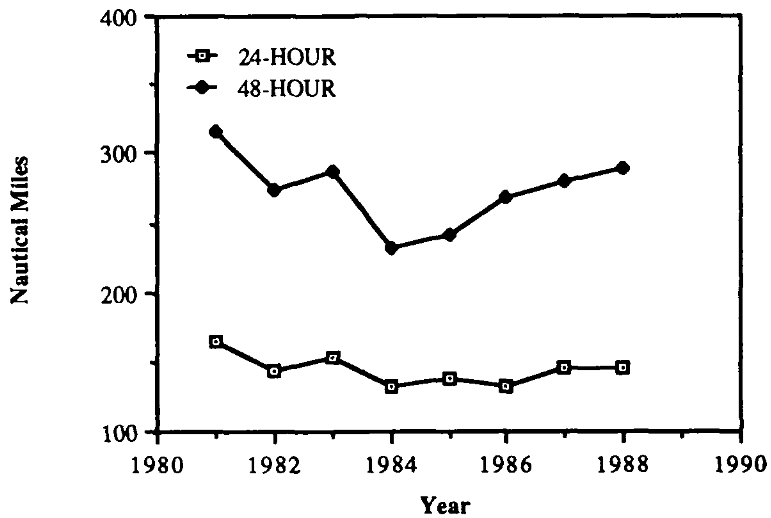


Figure 5-5. Annual mean forecast errors (nm) for all significant tropical cyclones in the South Pacific and South Indian Oceans

2. COMPARISON OF OBJECTIVE TECHNIQUES

a. GENERAL

Objective techniques used by JTWC are divided into five main categories:

(1) Extrapolation;

(2) Climatological and Analog Techniques;

(3) Model Output Statistics;

(4) Dynamic Models;

(5) Empirical and Analytical Techniques;

In September 1981, JTWC began to initialize its array of objective forecast techniques (described below) on the six-hour old preliminary best track position (an interpolative process) rather than the forecast (partially extrapolated) warning position, e.g. the 0600Z warning is now supported by objective techniques developed from the 0000Z preliminary best track position. This operational change has yielded several advantages:

(1) Techniques can now be requested much earlier in the warning development process, i.e. as soon as the track can be approximated by one or more fix positions after the valid time of the previous warning;

(2) Receipt of these techniques is virtually assured prior to the development of the next warning; and

(3) Improved (mean) forecast accuracy. This latter aspect arises because JTWC now has more reliable approximation of the short-term tropical cyclone movement. Further, since most of the objective techniques are biased towards persistence, this new procedure optimizes their performance and provides more consistent guidance on short-term movement, indirectly yielding a more accurate initial position estimate as well as lowering 24-hour forecast errors.

b. Description of Objective Techniques

(1) XTRP -- Forecast positions for 24- and 48-hours are derived from the extension of a straight line which connects the most recent and 12-hour old preliminary best track positions.

(2) CLIM -- A climatological aid providing 24-, 48-, and 72-hour tropical cyclone forecast positions (and intensity changes in the western North Pacific) based upon the position of the tropical cyclone. The output is based upon data records from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(3) HPAC -- Forecast positions are generated from a blend of climatology and persistence. The 24-, 48- and 72-hour positions are equally weighted between climatology and persistence. Persistence is a straight line extension of a line connecting the current and 12-hour old positions. Climatology is based on data from 1945 to 1981 for the western North Pacific Ocean and 1900 to 1981 for the North Indian Ocean.

(4) CLIPER -- A statistical regression technique based on climatology, current intensity, position and past movement. This technique is used as a crude measure of real forecast skill when verifying forecast accuracy.

(5) COSMOS -- A Model Output Statistics (MOS) routine based on the geostrophic steering at the 850-, 700-, and 500-mb levels. The steering is derived from the HATTRACK point advection model run on Global prognostic fields from the FLENUMOCEANCEN's NOGAPS prediction system. The MOS forecast is then blended with the 6-hour past movement to generate the forecast

track.

(6) Colorado State University Model (CSUM) -- A statistical-dynamic method developed by Matsumoto (1984) utilizes synoptic and persistence predictors by discretizing the forecast timeframe into three 24-hour time steps. Climatology is incorporated into the forecast via a stratification scheme based on the position of the tropical cyclone relative to the 500 mb subtropical ridge. Depending on whether the tropical cyclone is south, on, or north of the ridge, three sets of regression equations are used to determine the north-south and east-west displacements

(7) One-way Interactive Tropical Cyclone Model (OTCM) -- A coarse-mesh, three-layer in the vertical, primitive equation model with a 205 km grid spacing over a 6400 x 4700 km domain. The model's fields are computed around a bogused, digitized cyclone vortex using FLENUMOCEANCEN's Numerical Variational Analysis (NVA) or NOGAPS prognostic fields for the specified valid time. The past motion of the tropical cyclone is compared to initial steering fields and a bias correction is computed and applied to the model. FLENUMOCEANCEN's NOGAPS global prognostic fields are used at 12-hour intervals to update the model's boundaries. The resultant forecast positions are derived by locating the 850 mb vortex at six-hour intervals to 72-hours.

(8) TAPT -- An empirical technique which utilizes upper-tropospheric wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper-limits, and probable path of the cyclone.

(9) TYAN -- An updated analog program which combines the earlier versions TYFN 75 and INJAN 74. The program scans a 30-year climatology with a similar history (within a specified acceptance envelope) to the current tropical cyclone. For the western North Pacific Ocean, three forecasts of position and intensity are provided for 24-, 48-, and 72-hours: RECR - a weighted mean of all tropical cyclones which were categorized as "recurving" during their best track period; STRA - a weighted mean of all accepted tropical cyclones which were categorized as moving "straight" (westward) during their best track period: TOTL - a weighted mean of all accepted tropical cyclones, including those used in the RECR and STRA forecast. For the North Indian Ocean, a single (total) forecast track is provided for the 12-hour intervals to 72-hours.

(10) DVORAK -- An estimation of tropical cyclone's current and 24-hour forecast intensity is made from interpolation of satellite imagery (DVORAK, 1984) and provided to the forecaster. These intensity estimates are used in conjunction with other intensity related data and trends to forecast tropical cyclone intensity.

(11) HOLLAND/MARTIN -- The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. For the first time, diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "Beta-drift". The Holland/Martin wind radii technique replaces the more general Huntley (1980) technique.

c. Testing and Results

A comparison of selected techniques is included in Table 5-8 for all western North Pacific tropical cyclones, Table 5-9 for all North Indian Ocean tropical cyclones and Table 5-10 for the southern hemisphere. In these tables, " x-axis " refers to techniques listed vertically. For example (Table 5-8) in the 273 cases available for a (homogeneous) comparison, the average forecast error at 24-hours was 130 nm (241 km) for TOTL and 137 nm (254 km) for RECR. The difference of 7 nm (13 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-8 1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE WESTERN NORTH PACIFIC OCEAN

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y-X)

JTMC - OFFICIAL JTMC FORECAST
CLIP - CLIPER (CLIMATOLOGY AND PERSISTENCE)
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
TOTL - TOTAL ANALOG (TYAN 78)
CLIM - CLIMATOLOGY
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
XTRP - 12-HOUR EXTRAPOLATION

24-HOUR MEAN FORECAST ERROR (NM)

	JTMC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP
JTMC	373 114 114 0									
CLIP	334 114 132 18	334 132 132 0								
OTCM	345 113 124 11	323 133 127 -6	345 124 124 0							
CSUM	287 114 121 7	284 130 119 -11	280 125 122 -3	287 121 121 0						
RECR	273 113 137 24	272 124 136 12	264 126 136 10	246 122 136 14	273 137 137 0					
TOTL	307 113 139 26	296 133 133 0	298 126 139 13	261 119 136 17	273 137 130 -7	307 139 139 0				
COSM	346 [illegible] 131 20	323 131 133 2	335 124 131 7	283 121 127 6	266 136 130 -6	296 140 130 -10	346 131 131 0			
HPAC	349 113 131 18	332 133 128 -5	338 125 132 7	286 119 129 10	273 137 128 -9	304 137 131 -6	338 130 [illegible] 2	349 131 131 0		
CLIM	350 113 178 65	333 133 170 37	338 126 179 53	286 121 175 54	273 137 168 31	304 137 179 42	339 131 179 48	348 131 178 47	350 178 178 0	
XTRP	355 112 130 18	334 132 130 -2	343 124 130 6	285 119 131 12	273 137 127 -10	307 139 127 -12	344 130 129 -1	348 131 129 -2	349 177 129 -48	355 130 130 0

48-HOUR MEAN FORECAST ERROR (NM)

	JTMC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP
JTMC	262 216 216 0									
CLIP	238 219 267 48	249 260 260 0								
OTCM	242 215 221 6	236 256 226 -30	253 220 220 0							
CSUM	197 216 242 26	206 256 239 -17	204 219 239 20	208 238 238 0						
RECR	191 217 266 49	201 244 261 17	195 227 259 32	183 243 265 22	201 261 261 0					
TOTL	216 218 285 67	219 261 270 9	218 222 281 59	191 237 281 44	201 261 270 9	226 282 282 0				
COSM	245 213 283 70	239 258 294 26	244 222 269 47	205 239 259 20	196 258 264 6	216 285 271 -14	256 276 276 0			
HPAC	247 215 243 28	246 261 237 -24	246 222 238 16	207 237 236 -1	200 257 233 -24	222 272 234 -38	248 276 241 -35	258 240 240 0		
CLIM	247 215 297 82	247 260 277 17	245 222 290 68	206 238 280 42	200 257 270 13	222 272 282 10	248 275 295 20	257 239 290 51	258 289 289 0	
XTRP	254 215 291 76	249 260 294 34	252 220 291 71	207 238 298 60	201 261 289 28	226 282 288 6	255 276 291 15	257 239 291 52	258 289 291 2	265 292 292 0

72-HOUR MEAN FORECAST ERROR (NM)

	JTMC	CLIP	OTCM	CSUM	RECR	TOTL	COSM	HPAC	CLIM	XTRP
JTMC	183 315 315 0									
CLIP	167 323 413 90	182 398 398 0								
OTCM	160 305 309 4	163 373 315 -58	175 309 309 0							
CSUM	134 325 378 53	148 392 369 -23	144 306 366 60	149 367 367 0						
RECR	128 321 436 115	143 357 431 74	136 308 433 125	129 371 444 73	143 431 431 0					
TOTL	141 328 451 123	154 393 443 50	143 313 448 135	133 367 465 98	143 431 440 9	156 446 446 0				
COSM	173 307 520 213	176 388 518 130	170 309 466 157	146 368 455 87	139 424 445 21	150 445 487 42	188 505 505 0			
HPAC	172 [illegible] 359 48	178 389 349 -40	168 303 344 41	146 361 348 -13	140 406 337 -69	153 424 344 -80	181 491 348 -143	187 350 350 0		
CLIM	172 311 388 77	178 389 361 -28	168 303 373 70	146 361 356 -5	140 406 343 -63	153 424 358 -66	181 491 379 -112	187 350 377 27	187 377 377 0	
XTRP	179 314 482 168	182 398 482 84	175 309 478 169	149 367 499 132	143 431 486 55	156 446 490 44	188 505 475 -30	187 350 477 127	187 377 477 100	194 480 480 0

TABLE 5-9 1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHERN INDIAN OCEAN

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (X-Y)

JTWC - OFFICIAL JTWC FORECAST
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
CSUM - COLORADO STATE UNIVERSITY MODEL
TOTL - TOTAL ANALOG (TYAN 78)
CLIM - CLIMATOLOGY
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
XTRP - 12-HOUR EXTRAPOLATION

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		CSUM		HPAC		CLIM		XTRP	
JTWC	30	120										
	120	0										
OTCM	30	120	32	103								
	106	-14	103	0								
CSUM	28	117	30	101	30	207						
	220	103	207	106	207	0						
HPAC	30	120	32	103	30	207	32	112				
	117	-3	112	9	110	-97	112	0				
CLIM	30	120	32	103	30	207	32	112	32	116		
	117	-3	116	13	114	-93	116	4	116	0		
XTRP	29	122	31	104	29	202	31	113	31	118	31	130
	134	12	130	26	131	-71	130	17	130	12	130	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		CSUM		HPAC		CLIM		XTRP	
JTWC	18	219										
	219	0										
OTCM	18	219	20	211								
	227	8	211	0								
CSUM	17	220	19	216	19	539						
	576	356	539	323	539	0						
HPAC	18	219	20	211	19	539	20	202				
	185	-34	202	-9	209	-330	202	0				
CLIM	18	219	20	211	19	539	20	202	20	162		
	141	-78	162	-49	165	-374	162	-40	162	0		
XTRP	17	225	19	220	18	527	19	208	19	167	19	265
	251	26	265	45	277	-250	265	57	265	98	265	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		CSUM		HPAC		CLIM		XTRP	
JTWC	12	409										
	409	0										
OTCM	11	426	11	527								
	527	101	527	0								
CSUM	11	413	10	540	11	1043						
	1043	630	1034	494	1043	0						
HPAC	12	409	11	527	11	1043	12	298				
	298	-111	311	-216	313	-730	298	0				
CLIM	12	409	11	527	11	1043	12	298	12	231		
	231	-178	235	-292	233	-810	231	-67	231	0		
XTRP	11	428	10	557	10	1037	11	312	11	237	11	399
	399	-29	421	-136	433	-604	399	87	399	162	399	0

TABLE 5-10

1988 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISPHERE

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		HPAC		CLIM		XTRP	
JTWC	156	146								
	146	0								
OTCM	129	146	142	122						
	125	-21	122	0						
HPAC	143	147	141	121	156	124				
	126	-21	121	0	124	0				
CLIM	144	147	142	122	156	124	157	158		
	160	13	154	32	158	34	158	0		
XTRP	147	148	141	121	156	124	156	158	161	139
	136	-12	134	13	136	12	136	-22	139	0

NUMBER OF CASES	X-AXIS TECHNIQUE ERROR
Y-AXIS TECHNIQUE ERROR	ERROR DIFFERENCE (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		HPAC		CLIM		XTRP	
JTWC	112	290								
	290	0								
OTCM	91	274	121	238						
	237	-37	238	0						
HPAC	104	279	120	236	135	219				
	226	-53	219	-17	219	0				
CLIM	105	279	121	238	135	219	136	272		
	270	-9	272	34	271	52	272	0		
XTRP	107	289	120	236	135	219	135	271	138	283
	294	5	277	41	280	61	280	9	283	0

JTWC - OFFICIAL JTWC FORECAST
OTCM - ONE-WAY TROPICAL CYCLONE MODEL
TOTL - TOTAL ANALOG (TYAN 78)
HPAC - HALF CLIMATOLOGY AND PERSISTENCE BLEND
CLIM - CLIMATOLOGY
XTRP - 12-HOUR EXTRAPOLATION

72-HOUR MEAN FORECAST ERROR (NM)

	OTCM		HPAC		CLIM		XTRP	
OTCM	92	368						
	368	0						
HPAC	92	368	113	334				
	329	-39	334	0				
CLIM	92	368	113	334	113	431		
	444	76	431	97	431	0		
XTRP	92	368	113	334	113	431	114	412
	405	37	415	81	415	-16	412	0

Intentionally left blank.

CHAPTER VI - TROPICAL CYCLONE SUPPORT SUMMARY

The Pocket Tropical Cyclone Model (PTCM)

(Evans, J. L., Monash University, Australia and R. J. Miller, NAVENVPREDRSCHFAC)

The PTCM is a linear tropical cyclone motion prediction scheme incorporating the effects of large-scale environmental flow and west-northwestward propagation due to the rate of change of the Earth's vorticity over a given distance or (Beta-effect). The model is based on equations developed by Holland (1983) and has been operational in a modified form in the Australian region for a number of years. The current version of the model has been modified to accept FNOC data and produce up to 72-hour forecasts. The model is ready for testing.

The PTCM is being incorporated in the NEPRF Tropical Cyclone Forecast Simulation package which will be a resident program in the ATCF.

Tropical Cyclone Motion Diagnostic Tool

(Chu, J. H., NAVENVPREDRSCHFAC)

Based on the barotropic vorticity equation, a set of "Typhoon Motion Equations" has been developed. These equations can be used to diagnose interactions between the tropical cyclone and its environment. The equations provide forecasters with information on the impact of environmental changes on tropical cyclone motion. The equations have been tested using input of theoretical or analytical fields. Plans have been made to adapt these equations to FNOC fields and incorporate them in the Tropical Cyclone Forecast Simulation Package.

The Advanced Tropical Cyclone Model (ATCM)

(Hodur, R. M., NAVENVPREDRSCHFAC)

The ATCM was run in 1988 for use by JTWC forecasters. As in 1987, the ATCM again exhibited a strong northward bias. This bias was particularly evident with storms located deep in the tropics, despite numerous changes made after the 1987 tropical cyclone season. Also, erratic behavior was noticed on some forecasts of reasonably well-behaved storms. A description of problems discovered in the 1988 version of the ATCM follows.

The first problem concerns the data assimilation strategy used in the ATCM. Although the ATCM is not run until about six and a half hours after observation time, only those observations received up to three and a half hours after observation time were used. The ATCM used an assimilation cycle of 12-hours, as opposed to 6-hours for NOGAPS. This meant that all late and off-time data was not used by the ATCM, resulting in degraded analyses. In 1989, the ATCM will use either a later data cut-off time or NOGAPS analyses. Second, the radiation parameter-ization in the ATCM caused excessive cooling of the atmosphere and produced noise in the model. Noise due to clouds appears to contribute the largest error to tropical cyclone track forecasts. An improved treatment of clouds, based on that used by the European Center, is being tested in the ATCM and will be implemented prior to the 1989 tropical cyclone season. Test runs of several 1988 storms, using NOGAPS analyses and no clouds, have shown dramatic improvement in forecasting tropical cyclone tracks. Finally, the ATCM exhibits a northward bias during the first 6- to 12-hours of a forecast. This occurs even without physical parameterizations and has been related to either biases in the initial fields or the structure of the bogus circulation. A similar tendency has been noted by the National Meteorological Center for tropical cyclones in the Atlantic Ocean. Experiments with simple basic flows are being performed to isolate the cause of this erroneous movement.

Navy Tactical Applications Guide (NTAG), Volume 6

(Fett, R. W., NAVENVPREDRSCHFAC)

An effort is now underway to develop a series of examples demonstrating the use of high quality satellite data for analysis and forecasting in the tropics. Data from polar orbiting and geostationary satellites are used to study the evolution of certain weather effects or of a particular weather phenomenon at a given time. These examples are organized and collated for publishing in the NTAG Volume 6. NTAG Volume 6, Part I, "Tropical Weather Analysis and Forecast Applications," was distributed in June 1986. Part II, "Tropical Cyclones," is scheduled for completion in January 1989. In March 1989, work will begin on the development of the "Tropical Cyclone Forecaster's Handbook."

Automated Tropical Cyclone Forecasting System

(Tsui, T. L., R. J. Miller, and A. J. Schrader, NAVENVPREDRSCHFAC)

The Automated Tropical Cyclone Forecasting (ATCF) system is an IBM PC compatible software package currently being developed for JTWC. The ATCF is designed to allow JTWC forecasters to graphically display tropical cyclone forecast information, merge and analyze synoptic wind fields, provide objective fix guidance, select optimum objective forecast aids, and expedite the issuance of tropical cyclone warnings. One great advantage of the ATCF is standardization of tropical cyclone forecasting procedures. During the course of preparing a tropical cyclone warning, forecasters will avoid neglecting decisional steps or available options. The ATCF automatically saves all tropical cyclone data, computes real-time and post storm statistics, and allows forecasters to randomly access any past storm data. A communications package included in the ATCF simplifies data transfer between JTWC and FNOC.

The ATCF was installed at JTWC in January 1988 and activated for operational use in June 1988. The system was also installed at the AJTWC (located at NWOC) during October 1988. The system software has been provided to OAO Corporation for inclusion in the JTWC Automation Project.

North Pacific Tropical Cyclone Climatology

(Miller, R. J., T. L. Tsui and A. J. Schrader, NAVENVPREDRSCHFAC)

A tropical cyclone climatology for the North Pacific has been compiled and reviewed by EGPACOM and published by NEPRF. Data used for the western basin were taken from the JTWC Tropical Cyclone data base and covered a 40 year period from 1945 to 1984. Eastern basin data spanned a 34 year period from 1949 to 1982 and were obtained from the consolidated world-wide tropical cyclone data base at the National Climatic Data Center in Ashville, North Carolina. Tropical cyclones for both basins were sorted by day and month into twenty four 31-day overlapping periods. For each period, four charts are supplied: 1) actual storm paths; 2) mean storm paths; 3) average storm speed; and 4) storm constancy and frequency.

EOF Post-Processing Forecast Technique

(Chu, J. H., R. J. Miller and T. L. Tsui, NAVENVPREDRSCHFAC)

NEPRF has adapted the Empirical Orthogonal Function (EOF) tropical cyclone post-processing forecast scheme on the FNOC computer system. This EOF technique, developed by the Naval Postgraduate School, objectively recognizes salient patterns of large-scale horizontal wind fields relative to the center of a tropical cyclone. This information, in terms of EOF coefficients, is used via regression equations to modify tropical cyclone track forecasts produced by numerical models. Test results will be compiled after the 1988 western North Pacific tropical cyclone season.

ANNEX A

1. GENERAL

Due to the rapid growth of microcomputers in the meteorological community and to save publishing costs, tropical cyclone track data (with best track, initial warning, 24-, 48- and 72-hour JTWC forecasts) and fix data (satellite, aircraft, radar and synoptic) are now available separately upon request. The data will be in ASCII format on 5.25 inch "floppy" diskettes. The data sets are available on two diskettes. These include the western North Pacific Ocean (1 January - 31 December 1988) on one and North Indian Ocean (1 January - 31 December), South Western Pacific and South Indian Oceans (1 July 1987 - 30 June 1988) on the other. Agencies or individuals desiring these data sets should send the appropriate number of "floppy" diskettes (two if both data sets are desired) to NAVOCEANCOMCEN/JTWC Guam with their request. When the request is received, the data will be copied onto your diskettes and returned with the explanation of the data formats. The use of floppy diskettes should facilitate the transfer of these rather large data files to your computer.

2. WARNING VERIFICATION STATISTICS

a. WESTERN NORTH PACIFIC

This section includes verification statistics for each warning in the western North Pacific Ocean during 1988. Pre- and post-warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

TYPHOON ROY (01W)

	00h	24h	48h	72h
Average	13	123	246	401
# Cases	41	37	33	29

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
88010800	1	7.9N	171.5E	29.7	119.1	84.8	127.2	30	0	-10	-20	-35
88010806	2	8.0N	170.3E	32.0	80.3	109.0	197.7	35	0	-5	-25	-25
88010812	3	8.1N	169.2E	13.4	78.0	213.1	251.8	45	-5	-5	-40	-20
88010818	4	8.2N	168.0E	24.7	122.4	253.7	245.3	50	0	0	-30	-5
88010900	5	8.2N	166.7E	6.0	142.4	293.3	295.2	55	0	-10	-30	-10
88010906	6	8.3N	165.3E	13.3	165.8	270.1	296.4	60	0	-20	-25	-10
88010912	7	8.3N	163.7E	23.7	225.0	299.5	325.6	65	0	-35	-15	-5
88010918	8	8.4N	161.6E	30.3	177.5	236.7	337.3	70	-5	-35	-10	-5
88011000	9	8.8N	159.4E	13.4	97.6	254.4	492.3	85	-5	-10	5	15
88011006	10	9.2N	157.3E	8.4	63.1	290.0	519.5	95	0	5	15	15
88011012	11	9.9N	155.1E	21.4	130.2	349.8	608.9	115	-10	10	15	20
88011018	12	10.6N	153.0E	12.0	243.1	436.9	645.3	115	-5	15	15	25
88011100	13	11.4N	151.5E	25.2	209.8	391.6	652.9	115	-5	-10	-10	-5
88011106	14	11.7N	150.2E	6.0	140.9	309.1	480.9	110	-5	-10	-15	0
88011112	15	12.3N	149.1E	.0	18.5	101.2	281.9	110	0	0	0	0
88011118	16	12.9N	147.9E	5.8	11.6	64.3	296.1	105	5	-10	-5	-5
88011200	17	13.1N	146.7E	6.0	34.7	102.2	351.6	110	-5	-10	0	-5
88011206	18	13.8N	145.6E	11.7	36.7	198.8	318.2	110	-5	0	10	-5
88011212	19	14.0N	144.3E	11.6	141.1	124.2	117.7	110	0	0	5	-10
88011218	20	14.6N	143.3E	.0	89.3	239.8	416.4	110	0	5	0	-5
88011300	21	15.2N	142.4E	13.3	122.2	344.0	566.0	105	0	5	0	5
88011306	22	15.3N	141.7E	8.3	214.0	534.6	866.4	105	-5	0	-15	0
88011312	23	15.2N	141.0E	11.6	225.7	479.6	739.8	100	0	5	-10	20
88011318	24	14.7N	140.2E	8.3	193.5	465.0	645.8	95	5	0	-5	30
88011400	25	14.0N	139.1E	13.3	234.4	502.5	659.6	90	0	-10	0	25

88011406	26	13.2N	137.4E	37.0	234.2	468.5	633.7	85	0	-15	0	25
88011412	27	12.6N	135.8E	8.4	64.7	46.3	76.0	85	-5	-20	0	0
88011418	28	12.[illegible]	133.9E	11.7	77.0	24.7	50.0	90	-10	-15	10	5
88011500	29	12.4N	131.7E	6.0	93.5	146.3	145.8	90	[illegible]	-5	10	5
88011506	30	12.6N	129.7E	6.0	117.0	169.2	N/A	90	0	-5	15	N/A
88011512	31	12.8N	127.7E	.0	110.8	145.8	N/A	90	-5	10	15	N/A
88011518	32	13.0N	125.9E	13.1	157.5	163.0	N/A	85	-5	20	15	N/A
88011600	33	13.1N	124.6E	8.4	24.7	16.7	N/A	75	-5	10	10	N/A
88011606	34	13.1N	123.3E	26.3	81.6	N/A	N/A	65	0	15	N/A	N/A
88011612	35	13.7N	122.2E	6.0	87.6	N/A	N/A	50	10	10	N/A	N/A
88011618	36	13.8N	121.0E	6.0	94.9	N/A	N/A	40	5	10	N/A	N/A
88011700	37	13.4N	119.4E	8.4	96.2	N/A	N/A	40	0	5	N/A	N/A
88011706	38	13.7N	118.0E	18.5	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88011712	39	13.8N	116.6E	23.3	N/A	N/A	N/A	30	0	N/A	N/A	N/A
88011718	40	14.0N	115.4E	.0	N/A	N/A	N/A	25	0	N/A	N/A	N/A
88011800	41	13.9N	114.5E	8.4	N/A	N/A	N/A	25	0	N/A	N/A	N/A

Typhoon Susan (02W)

	00h	24h	48h	72h
Average	18	146	378	423
# Cases	17	13	9	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88053006	1	18.4N	119.4E	17.1	181.7	255.8	161.2	35	0	-20	-2	-5
88053012	2	18.2N	119.0E	13.3	108.3	127.3	208.9	45	-5	-15	-15	-5
88053018	3	18.4N	118.5E	23.6	61.4	98.2	385.7	50	-5	-5	-5	15
88053100	4	18.6N	118.2E	24.0	124.5	334.7	707.6	55	5	10	20	45
88053106	5	19.0N	118.0E	13.3	56.0	315.0	653.3	60	5	0	5	35
88053112	6	19.4N	117.9E	8.2	95.3	402.4	N/A	65	5	5	15	N/A
88053118	7	19.8N	117.9E	18.0	156.1	503.8	N/A	65	5	-10	5	N/A
88060100	8	20.2N	117.9E	23.3	246.5	664.2	N/A	70	0	-10	15	N/A
88060106	9	20.6N	118.2E	23.3	307.6	709.1	N/A	75	-5	-10	25	N/A
88060112	10	21.1N	118.7E	12.7	61.1	N/A	N/A	75	0	10	N/A	N/A
88060118	11	21.7N	119.8E	49.3	94.0	N/A	N/A	75	0	20	N/A	N/A
88060200	12	22.3N	121.2E	12.0	135.7	N/A	N/A	70	5	30	N/A	N/A
88060206	13	23.5N	122.7E	13.2	277.8	N/A	N/A	65	5	25	N/A	N/A
88060212	14	24.8N	124.4E	36.4	N/A	N/A	N/A	55	5	N/A	N/A	N/A
88060218	15	25.5N	126.5E	12.4	N/A	N/A	N/A	45	-5	N/A	N/A	N/A
88060300	16	25.6N	128.4E	16.2	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88060306	17	26.3N	130.2E	6.0	N/A	N/A	N/A	25	5	N/A	N/A	N/A

Tropical Depression (03W)

	00h	24h	48h	72h
Average	19	169	N/A	N/A
# Cases	6	4	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88060406	1	18.8N	126.0E	18.1	160.6	N/A	N/A	30	0	10	N/A	N/A
88060412	2	19.3N	125.2E	39.8	101.0	N/A	N/A	30	0	20	N/A	N/A
88060418	3	19.9N	124.5E	20.8	184.5	N/A	N/A	30	0	15	N/A	N/A
88060500	4	20.5N	123.7E	13.2	232.8	N/A	N/A	30	0	25	N/A	N/A
88060506	5	21.0N	122.4E	5.6	N/A	N/A	N/A	30	0	N/A	N/A	N/A
88060512	6	21.5N	121.1E	16.4	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Typhoon Thad (04W)

	00h	24h	48h	72h
Average	24	143	274	329
# Cases	20	16	12	8

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88062000	1	8.3N	133.1E	21.6	180.1	235.2	352.3	35	0	5	15	-15
88062006	2	9.3N	132.2E	48.0	210.0	259.6	474.0	35	0	20	-5	-30
88062012	3	10.7N	131.8E	42.4	97.7	33.9	242.8	40	0	20	10	10
88062018	4	12.0N	131.2E	46.3	205.5	195.5	47.5	45	0	15	20	35
88062100	5	13.0N	129.9E	50.3	81.1	91.2	191.9	50	-5	0	0	25
88062106	6	13.9N	128.6E	8.4	109.6	16.5	271.6	45	0	-20	-20	10
88062112	7	14.6N	127.5E	5.8	50.9	114.2	412.9	45	0	-20	-10	20
88062118	8	15.2N	126.6E	8.3	38.7	279.9	639.8	55	-5	-10	0	30
88062200	9	15.7N	125.8E	98.4	110.8	439.6	N/A	60	-5	0	25	N/A
88062206	10	16.2N	125.[illegible]E	26.0	180.0	513.4	N/A	65	0	5	30	N/A
88062212	11	16.7N	124.8E	5.7	181.8	505.7	N/A	70	5	0	15	N/A
88062218	12	17.6N	124.5E	30.0	282.5	605.0	N/A	70	-5	-10	15	N/A
88062300	13	18.7N	124.7E	13.3	110.1	N/A	N/A	70	-5	0	N/A	N/A
88062306	14	20.0N	125.2E	12.8	168.5	N/A	N/A	70	-5	10	N/A	N/A
88062312	15	21.3N	125.7E	.0	164.2	N/A	N/A	65	0	15	N/A	N/A
88062318	16	22.7N	126.6E	5.5	128.2	N/A	N/A	65	0	20	N/A	N/A
88062400	17	24.1N	127.7E	16.4	N/A	N/A	N/A	55	5	N/A	N/A	N/A
88062406	18	25.3N	129.0E	17.3	N/A	N/A	N/A	45	10	N/A	N/A	N/A
88062412	19	26.5N	130.4E	10.7	N/A	N/A	N/A	40	5	N/A	N/A	N/A
88062418	20	27.7N	131.9E	21.2	N/A	N/A	N/A	35	5	N/A	N/A	N/A

Tropical Storm Vanessa (05W)

	00h	24h	48h	72h
Average	27	194	386	N/A
# Cases	11	7	3	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88062612	1	7.6N	130.3E	34.8	228.1	486.2	N/A	30	0	10	5	N/A
88062618	2	8.3N	129.3E	6.0	125.9	322.2	N/A	35	-5	0	-10	N/A
88062700	3	9.1N	127.8E	13.3	170.0	352.1	N/A	40	-5	-10	-5	N/A
88062706	4	9.9N	126.2E	23.6	194.1	N/A	N/A	45	-10	-10	N/A	N/A
88062712	5	10.7N	124.4E	23.6	186.2	N/A	N/A	35	0	-10	N/A	N/A
88062718	6	11.4N	122.3E	30.0	227.1	N/A	N/A	35	0	0	N/A	N/A
88062800	7	12.3N	120.3E	42.6	226.7	N/A	N/A	40	0	15	N/A	N/A
88062806	8	13.6N	118.6E	63.1	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88062812	9	15.2N	117.2E	29.0	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88062818	10	17.3N	115.8E	18.9	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88062900	11	19.4N	114.7E	21.3	N/A	N/A	N/A	35	5	N/A	N/A	N/A

Typhoon Warren (06W)

	00h	24h	48h	72h
Average	19	86	152	246
# Cases	30	28	23	16

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88071218	1	12.1N	145.3E	13.2	162.1	268.5	334.1	30	0	5	-10	-25
88071300	2	12.3N	144.7E	50.2	148.5	292.1	345.2	35	0	5	-10	-20
88071306	3	12.4N	143.8E	24.2	90.9	202.8	190.6	35	0	-5	-20	-25
88071312	4	12.4N	142.9E	8.4	56.2	103.5	77.4	35	0	-15	-30	-30
88071318	5	12.5N	142.0E	33.6	74.3	89.3	60.0	40	-5	-20	-35	-45
88071400	6	12.5N	141.2E	41.4	76.3	47.2	71.3	45	-5	-20	-30	-45
88071406	7	12.7N	140.4E	11.7	61.4	60.2	160.9	55	-15	-30	-35	-40
88071412	8	12.7N	139.6E	6.0	16.7	99.5	212.6	60	-10	-20	-20	-20
88071418	9	12.8N	138.8E	24.2	26.7	147.5	261.0	65	-10	-15	-25	-10
88071500	10	12.8N	138.0E	30.6	130.0	316.7	414.5	70	-5	0	-15	15
88071506	11	13.0N	137.3E	30.6	214.8	412.[illegible]	4[illegible]9.1	80	0	0	-5	25
88071512	12	13.3N	136.2E	13.1	81.3	220.4	2[illegible].6	90	0	5	-5	10

88071518	13	13.6N	134.9E	18.5	106.7	217.3	272.8	90	-5	-35	-40	-30
88071600	14	14.2N	133.5E	25.1	115.2	190.9	359.3	90	0	-20	-5	10
88071606	15	14.8N	131.9E	34.7	140.0	190.3	277.3	95	-5	-15	-5	-10
88071612	16	15.2N	130.2E	16.7	80.0	109.6	145.9	100	-5	-30	-20	-5
88071618	17	15.9N	128.5E	8.3	48.3	97.4	N/A	110	0	-25	-25	N/A
88071700	18	16.5N	127.0E	18.9	36.4	90.9	N/A	115	0	20	20	N/A
88071706	19	16.9N	125.4E	5.7	34.5	68.7	N/A	110	5	5	15	N/A
88071712	20	17.8N	124.0E	5.7	87.3	73.9	N/A	110	-5	-25	-20	N/A
88071718	21	18.4N	122.6E	5.7	32.8	6.0	N/A	105	-10	-20	-10	N/A
88071800	22	18.8N	121.6E	16.5	45.6	73.8	N/A	95	-10	15	5	N/A
88071806	23	19.3N	120.5E	13.3	54.3	126.1	N/A	90	-10	25	5	N/A
88071812	24	20.0N	119.5E	.0	44.7	N/A	N/A	85	-5	20	N/A	N/A
88071818	25	20.8N	118.1E	28.8	66.0	N/A	N/A	80	0	30	N/A	N/A
88071900	26	21.7N	117.0E	21.2	29.0	N/A	N/A	75	5	15	N/A	N/A
88071906	27	22.7N	116.3E	18.0	170.2	N/A	N/A	65	10	5	N/A	N/A
88071912	28	23.5N	115.5E	25.1	183.2	N/A	N/A	50	15	10	N/A	N/A
88071918	29	24.2N	114.4E	24.0	N/A	N/A	N/A	40	10	N/A	N/A	N/A
88072000	30	25.0N	113.5E	21.0	N/A	N/A	N/A	30	10	N/A	N/A	N/A

Tropical Storm Agnes (07W)

	00h	24h	48h	72h
Average	33	322	714	N/A
# Cases	8	5	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88072900	1	20.9N	140.7E	36.4	295.8	714.1	N/A	30	0	-5	5	N/A
88072906	2	21.8N	140.6E	26.5	380.0	N/A	N/A	30	0	0	N/A	N/A
88072912	3	22.8N	140.8E	39.7	401.7	N/A	N/A	35	-5	-5	N/A	N/A
88072918	4	24.0N	141.7E	81.4	427.2	N/A	N/A	40	-10	0	N/A	N/A
88073000	5	25.7N	142.4E	5.4	109.1	N/A	N/A	45	-5	5	N/A	N/A
88073006	6	27.9N	142.7E	29.1	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88073012	7	29.9N	142.6E	13.1	N/A	N/A	N/A	35	5	N/A	N/A	N/A
88073018	8	31.7N	143.1E	35.5	N/A	N/A	N/A	35	0	N/A	N/A	N/A

Tropical Storm Bill (08W)

	00h	24h	48h	72h
Average	12	119	N/A	N/A
# Cases	5	3	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88080700	1	27.4N	125.6E	10.7	111.2	N/A	N/A	35	0	5	N/A	N/A
88080706	2	28.2N	124.2E	6.0	123.5	N/A	N/A	45	0	5	N/A	N/A
88080712	3	28.9N	122.7E	6.0	123.8	N/A	N/A	45	0	15	N/A	N/A
88080718	4	29.7N	121.0E	18.7	N/A	N/A	N/A	40	-5	N/A	N/A	N/A
88080800	5	30.7N	119.4E	20.8	N/A	N/A	N/A	30	0	N/A	N/A	N/A

Tropical Storm Clara (09W)

	00h	24h	48h	72h
Average	24	89	N/A	N/A
# Cases	6	3	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88081018	1	28.7N	160.1E	10.5	107.6	N/A	N/A	40	-5	0	N/A	N/A
88081100	2	28.5N	160.3E	19.8	73.1	N/A	N/A	45	-5	5	N/A	N/A
88081106	3	28.4N	160.5E	35.6	86.5	N/A	N/A	45	0	0	N/A	N/A
88081112	4	28.5N	160.5E	18.8	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88081118	5	28.9N	160.6E	16.9	N/A	N/A	N/A	35	-5	N/A	N/A	N/A
88081200	6	29.5N	160.9E	44.8	N/A	N/A	N/A	35	-5	N/A	N/A	N/A

Typhoon Doyle (10W)

	00h	24h	48h	72h
Average	14	106	316	626
# Cases	24	20	16	11

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88081512	1	20.0N	168.1E	13.3	30.5	237.1	584.4	40	0	-45	-45	-10
88081518	2	20.1N	167.1E	11.3	100.6	377.7	743.2	55	-5	-45	-35	-25
88081600	3	20.3N	166.2E	21.2	212.8	531.1	859.7	70	-5	-35	-20	-10
88081606	4	20.6N	165.5E	18.9	171.3	523.3	912.7	85	0	-15	-5	5
88081612	5	21.0N	164.8E	13.2	191.1	557.1	935.7	100	0	20	45	45
88081618	6	21.6N	164.4E	8.2	156.7	469.1	760.2	115	0	30	35	30
88081700	7	22.4N	164.3E	26.4	169.2	407.0	628.8	115	0	-15	-5	-5
88081706	8	23.1N	164.2E	12.0	140.1	368.1	566.9	110	-10	-10	0	-5
88081712	9	23.9N	164.3E	16.3	150.8	294.1	394.4	110	0	15	15	5
88081718	10	25.1N	164.7E	34.2	143.3	257.4	322.3	100	0	-5	-5	-15
88081800	11	26.1N	165.3E	21.0	49.1	44.6	180.4	95	0	-15	-25	-20
88081806	12	27.0N	165.9E	13.1	24.6	150.3	N/A	90	0	-15	-30	N/A
88081812	13	28.0N	166.7E	6.0	93.6	261.7	N/A	85	0	-20	-25	N/A
88081818	14	28.9N	167.6E	.0	135.9	303.3	N/A	80	0	-10	-25	N/A
88081900	15	29.6N	168.5E	8.0	69.8	179.9	N/A	75	5	-10	-15	N/A
88081906	16	30.2N	169.3E	7.9	39.1	103.3	N/A	70	0	-15	-20	N/A
88081912	17	30.7N	170.2E	28.5	71.8	N/A	N/A	70	-5	-15	N/A	N/A
88081918	18	31.1N	170.9E	11.9	19.2	N/A	N/A	65	0	-10	N/A	N/A
88082000	19	31.6N	171.5E	11.8	33.5	N/A	N/A	65	0	-5	N/A	N/A
88082006	20	32.0N	172.1E	12.0	133.6	N/A	N/A	65	0	-5	N/A	N/A
88082012	21	32.5N	173.0E	6.0	N/A	N/A	N/A	60	5	N/A	N/A	N/A
88082018	22	33.5N	173.4E	13.0	N/A	N/A	N/A	55	0	N/A	N/A	N/A
88082100	23	34.3N	173.5E	25.5	N/A	N/A	N/A	50	0	N/A	N/A	N/A
88082106	24	34.9N	173.5E	18.0	N/A	N/A	N/A	50	-10	N/A	N/A	N/A

Tropical Storm Elsie (11W)

	00h	24h	48h	72h
Average	31	206	N/A	N/A
# Cases	10	4	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88082812	1	21.9N	158.2E	5.6	362.3	N/A	N/A	35	0	20	N/A	N/A
88082818	2	22.3N	159.2E	47.5	205.2	N/A	N/A	35	0	15	N/A	N/A
86082900	3	23.1N	159.9E	82.0	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88082906	4	24.2N	160.8E	40.7	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88082912	5	25.4N	161.3E	16.2	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88082918	6	26.7N	161.6E	13.1	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88083100	7	32.6N	158.8E	26.0	132.7	N/A	N/A	45	-5	0	N/A	N/A
88083106	8	34.0N	157.3E	6.0	124.6	N/A	N/A	45	0	0	N/A	N/A
88083112	9	35.8N	156.0E	25.9	N/A	N/A	N/A	40	-5	N/A	N/A	N/A
88083118	10	37.1N	155.4E	51.6	N/A	N/A	N/A	35	-5	N/A	N/A	N/A

Typhoon Fabian (12W)

	00h	24h	48h	72h
Average	21	141	177	279
# Cases	18	14	10	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88083000	1	31.1N	144.8E	23.7	178.8	449.8	534.1	40	0	0	-5	-35
88083006	2	31.0N	145.5E	23.7	143.9	405.4	458.0	45	-5	5	-5	-40
88083012	3	31.0N	146.4E	11.9	72.7	84.6	312.0	50	-5	5	0	-5
88083018	4	31.1N	147.5E	15.8	26.1	75.0	200.2	55	0	20	10	-10
88083100	5	31.2N	148.6E	13.1	36.4	92.1	46.0	55	0	15	5	-5
88083106	6	31.4N	149.8E	15.8	115.8	182.1	125.8	55	0	0	-10	0
88083112	7	31.4N	150.7E	19.5	146.2	117.3	N/A	55	-10	-30	-45	N/A
88083118	8	31.4N	151.4E	23.7	128.2	90.3	N/A	55	-10	-25	-40	N/A
88090100	9	31.4N	152.2E	30.7	103.9	119.3	N/A	60	0	-25	-35	N/A

88090106	10	31.4N	153.2E	31.3	184.2	162.0	N/A	65	-10	-30	-20	N/A
88090112	11	31.7N	153.7E	11.8	166.5	N/A	N/A	65	-10	-20	N/A	N/A
88090118	12	32.4N	153.8E	28.0	77.2	N/A	N/A	65	-10	-35	N/A	N/A
88090200	13	33.2N	153.8E	13.0	245.2	N/A	N/A	70	5	15	N/A	N/A
88090206	14	34.0N	153.7E	.0	359.1	N/A	N/A	75	0	15	N/A	N/A
88090212	15	35.5N	153.9E	.0	N/A	N/A	N/A	75	0	N/A	N/A	N/A
88090218	16	36.8N	154.7E	15.6	N/A	N/A	N/A	75	-10	N/A	N/A	N/A
88090300	17	39.0N	156.9E	4.7	N/A	N/A	N/A	70	-5	N/A	N/A	N/A
88090306	18	41.3N	160.0E	102.0	N/A	N/A	N/A	55	-10	N/A	N/A	N/A

Tropical Storm Gay (13W)

	00h	24h	48h	72h
Average	33	98	N/A	N/A
# Cases	6	3	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88090218	1	27.5N	136.8E	35.9	88.5	N/A	N/A	40	-5	20	N/A	N/A
88090300	2	28.4N	138.0E	32.2	75.9	N/A	N/A	45	0	30	N/A	N/A
88090306	3	29.4N	139.3E	39.7	132.1	N/A	N/A	45	0	35	N/A	N/A
88090312	4	30.5N	140.9E	31.6	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88090318	5	31.6N	142.6E	16.5	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88090400	6	32.7N	144.2E	44.6	N/A	N/A	N/A	35	-5	N/A	N/A	N/A

Typhoon Hal (14W)

	00h	24h	48h	72h
Average	18	122	249	355
# Cases	37	33	29	25

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88090800	1	17.5N	157.9E	41.9	177.0	214.0	177.5	30	0	-5	0	-15
88090806	2	18.0N	156.9E	11.4	134.0	178.8	226.9	30	0	-5	-5	-30
88090812	3	18.4N	155.8E	8.3	116.2	110.3	231.7	35	0	10	5	-30
88090818	4	18.9N	154.5E	17.0	51.9	137.3	308.4	40	-5	0	-15	-40
88090900	5	19.6N	153.1E	34.5	20.6	150.9	298.2	45	0	10	-5	-20
88090906	6	20.3N	152.0E	18.0	43.5	227.6	319.2	45	0	10	-20	-20
88090912	7	20.8N	151.0E	8.2	137.7	384.0	453.4	45	0	5	-30	-20
88090918	8	21.0N	150.2E	20.6	133.9	327.0	371.6	45	0	-15	-40	-50
88091000	9	21.1N	149.2E	8.2	139.3	327.9	407.2	50	-5	-20	-35	-45
88091006	10	21.2N	148.4E	5.6	141.6	313.9	341.7	55	0	-25	-35	-45
88091012	11	21.1N	147.7E	5.6	156.1	191.6	206.8	60	-5	-30	-25	-15
88091018	12	20.9N	147.0E	12.7	75.0	211.1	313.6	70	-5	-15	-5	10
88091100	13	20.5N	146.5E	26.5	157.5	271.9	424.1	80	-10	-10	0	10
88091106	14	20.1N	146.2E	8.2	152.0	306.5	504.9	95	-5	5	10	25
88091112	15	19.7N	145.8E	13.3	149.3	303.7	485.1	105	-5	10	15	35
88091118	16	20.0N	145.4E	25.6	144.9	302.7	448.8	105	-5	10	20	40
88091200	17	20.4N	145.6E	48.3	198.0	381.9	537.7	105	-5	5	15	40
88091206	18	21.0N	145.5E	47.6	158.6	352.2	511.3	105	-5	0	15	40
88091212	19	21.5N	145.4E	16.4	126.0	318.7	455.5	105	-5	0	25	45
88091218	20	22.3N	145.1E	17.7	90.2	228.5	342.6	105	-5	5	30	50
88091300	21	23.1N	144.7E	12.0	49.8	104.1	236.4	105	-5	15	35	40
88091306	22	23.9N	144.3E	8.1	12.2	33.6	120.2	105	0	25	35	40
88091312	23	25.0N	143.9E	6.0	8.0	44.6	198.1	105	0	30	40	45
88091318	24	26.0N	143.7E	5.4	38.2	46.6	361.8	100	0	10	20	25
88091400	25	27.1N	143.4E	16.1	23.8	146.2	601.8	100	-10	-10	-5	-5
88091406	26	28.2N	143.2E	18.8	48.3	217.0	N/A	90	-5	0	0	N/A
88091412	27	29.3N	142.9E	5.2	86.5	383.9	N/A	85	-10	-5	-10	N/A
88091418	28	30.3N	142.3E	15.8	155.4	457.0	N/A	80	-5	0	-5	N/A
88091500	29	31.3N	142.0E	13.0	180.8	561.6	N/A	80	-5	-10	0	N/A
88091506	30	32.2N	142.3E	15.2	139.4	N/A	N/A	75	0	0	N/A	N/A
88091512	31	33.2N	142.9E	16.2	162.3	N/A	N/A	70	5	0	N/A	N/A
88091518	32	34.4N	143.6E	9.9	276.9	N/A	N/A	65	0	-5	N/A	N/A
88091600	33	35.7N	144.8E	18.9	371.8	N/A	N/A	65	0	0	N/A	N/A

88091606	34	37.0N	146.6E	22.6	N/A	N/A	N/A	60	-5	N/A	N/A	N/A
88091612	35	38.4N	149.1E	38.1	N/A	N/A	N/A	55	-5	N/A	N/A	N/A
88091618	36	39.7N	152.4E	23.8	N/A	N/A	N/A	50	-5	N/A	N/A	N/A
88091700	37	40.4N	156.3E	37.7	N/A	N/A	N/A	45	0	N/A	N/A	N/A

Typhoon Uleki (01C)

	00h	24h	48h	72h
Average	17	82	146	153
# Cases	21	19	15	11

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88090806	1	25.2N	179.8W	6.0	39.4	63.6	78.7	90	0	-10	-20	-20
88090812	2	25.6N	178.7E	18.8	90.7	226.0	332.9	90	0	-10	-20	-15
88090818	3	26.1N	177.3E	17.2	27.8	105.3	122.7	90	0	-10	-20	-15
88090900	4	26.7N	176.1E	20.1	36.7	70.9	120.1	90	-5	-20	-30	-20
88090906	5	27.2N	175.2E	8.0	93.8	139.5	212.2	90	-5	-20	-20	-20
88090912	6	27.5N	174.3E	.0	94.1	129.8	230.7	90	5	-5	-5	-10
88090918	7	27.6N	173.5E	16.0	55.9	87.7	136.9	90	0	-15	-10	-10
88091000	8	27.6N	172.8E	12.2	86.6	98.7	126.4	90	-10	-25	-15	-15
88091006	9	27.8N	172.2E	18.8	99.5	125.8	65.2	90	-15	-10	-5	-5
88091012	10	28.2N	171.4E	19.9	70.2	119.4	119.6	90	-10	0	0	5
88091018	11	28.8N	170.7E	6.0	72.6	150.4	139.8	90	-10	-10	-10	10
88091100	12	29.4N	170.3E	10.5	97.4	302.0	N/A	90	0	-10	-15	N/A
88091106	13	29.8N	169.7E	26.0	151.4	398.9	N/A	80	10	0	-5	N/A
88091112	14	30.2N	169.3E	13.1	39.0	100.6	N/A	75	0	10	15	N/A
88091118	15	30.6N	169.0E	11.9	63.0	74.7	N/A	75	0	0	15	N/A
88091200	16	31.0N	168.6E	7.9	102.0	N/A	N/A	70	5	-5	N/A	N/A
88091206	17	31.2N	168.1E	23.7	145.9	N/A	N/A	70	0	0	N/A	N/A
88091212	18	31.2N	167.6E	48.3	123.7	N/A	N/A	65	0	-5	N/A	N/A
88091218	19	31.2N	167.1E	24.5	73.9	N/A	N/A	65	-5	0	N/A	N/A
88091300	20	31.3N	166.4E	26.3	N/A	N/A	N/A	60	-5	N/A	N/A	N/A
88091306	21	31.6N	165.4E	26.3	N/A	N/A	N/A	55	-5	N/A	N/A	N/A

Tropical Storm Irma (15W)

	00h	24h	48h	72h
Average	17	76	94	158
# Cases	16	14	10	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88091200	1	22.6N	160.1E	21.1	91.9	60.9	84.7	40	0	5	0	0
88091206	2	23.2N	159.9E	12.0	80.5	78.2	93.9	45	0	5	5	5
88091212	3	23.6N	159.6E	25.1	52.0	24.1	57.8	45	0	-5	-10	-5
88091218	4	23.9N	159.0E	17.5	54.4	140.0	210.0	45	0	-5	-10	0
88091300	5	24.4N	158.4E	6.0	134.5	214.6	238.3	45	0	0	-10	10
88091306	6	24.9N	158.0E	6.0	87.6	157.2	264.3	50	5	5	5	20
88091312	7	25.2N	157.9E	12.4	34.2	72.4	N/A	55	0	5	10	N/A
88091318	8	25.7N	157.8E	36.4	131.1	143.8	N/A	55	0	5	15	N/A
88091400	9	26.3N	157.6E	16.1	57.6	13.1	N/A	55	0	10	25	N/A
88091406	10	26.6N	157.4E	17.2	45.9	36.4	N/A	55	0	15	30	N/A
88091412	11	27.0N	157.0E	18.8	67.8	N/A	N/A	55	0	-10	N/A	N/A
88091418	12	27.3N	156.7E	5.3	39.8	N/A	N/A	55	0	-5	N/A	N/A
88091500	13	27.6N	156.4E	8.0	69.2	N/A	N/A	55	-5	0	N/A	N/A
88091506	14	28.3N	156.0E	36.7	124.0	N/A	N/A	50	0	15	N/A	N/A
88091512	15	28.9N	155.7E	15.9	N/A	N/A	N/A	45	-5	N/A	N/A	N/A
88091518	16	29.8N	155.6E	19.7	N/A	N/A	N/A	40	-5	N/A	N/A	N/A

Tropical Storm Jeff (16W)

	00h	24h	48h	72h
Average	15	64	103	N/A
# Cases	9	5	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88091400	1	16.3N	136.7E	21.4	77.0	103.3	N/A	35	0	-5	10	N/A
88091406	2	17.1N	137.5E	12.9	62.0	N/A	N/A	40	5	5	N/A	N/A
88091412	3	18.0N	138.2E	8.3	79.6	N/A	N/A	45	0	10	N/A	N/A
88091418	4	19.0N	138.9E	8.3	60.0	N/A	N/A	45	0	15	N/A	N/A
88091500	5	20.1N	139.5E	24.7	45.0	N/A	N/A	45	-5	5	N/A	N/A
88091506	6	21.4N	140.0E	30.4	N/A	N/A	N/A	45	0	N/A	N/A	N/A
88091512	7	22.8N	140.5E	.0	N/A	N/A	N/A	35	5	N/A	N/A	N/A
88091518	8	24.0N	141.0E	18.0	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88091600	9	25.3N	141.5E	13.2	N/A	N/A	N/A	35	0	N/A	N/A	N/A

Tropical Storm Kit (17W)

	00h	24h	48h	72h
Average	26	96	120	N/A
# Cases	12	8	4	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88091906	1	16.7N	124.2E	26.6	75.2	56.4	N/A	30	0	5	-5	N/A
88091912	2	17.5N	122.9E	18.2	46.4	124.7	N/A	30	0	-10	-20	N/A
88091918	3	18.0N	121.8E	42.4	96.1	129.7	N/A	35	0	0	-5	N/A
88092000	4	18.3N	120.8E	49.3	121.9	170.5	N/A	35	0	-5	10	N/A
88092006	5	18.7N	119.8E	30.8	107.2	N/A	N/A	35	0	-10	N/A	N/A
88092012	6	19.3N	119.1E	51.3	145.3	N/A	N/A	40	0	-5	N/A	N/A
88092018	7	19.8N	118.5E	34.4	112.1	N/A	N/A	45	0	0	N/A	N/A
88092100	8	20.4N	118.0E	8.2	68.6	N/A	N/A	50	-5	5	N/A	N/A
88092106	9	20.8N	117.5E	20.7	N/A	N/A	N/A	55	0	N/A	N/A	N/A
88092112	10	21.4N	117.0E	11.2	N/A	N/A	N/A	60	0	N/A	N/A	N/A
88092118	11	22.3N	116.5E	12.0	N/A	N/A	N/A	55	0	N/A	N/A	N/A
88092200	12	23.1N	116.1E	12.6	N/A	N/A	N/A	45	0	N/A	N/A	N/A

Tropical Storm Lee (18W)

	00h	24h	48h	72h
Average	21	127	221	265
# Cases	15	11	7	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88092100	1	18.4N	134.5E	22.8	84.7	150.9	99.8	35	0	-10	0	20
88092106	2	18.4N	133.4E	52.7	117.9	185.7	231.0	45	0	0	10	35
88092112	3	18.5N	132.3E	18.0	88.0	148.6	465.4	50	5	10	20	45
88092118	4	18.8N	131.4E	32.1	107.0	237.5	N/A	55	0	10	20	N/A
88092200	5	19.2N	130.5E	12.0	66.9	194.0	N/A	55	0	-5	5	N/A
88092206	6	19.6N	129.7E	12.8	36.4	286.9	N/A	55	-10	-10	10	N/A
88092212	7	20.0N	128.7E	16.9	30.0	346.1	N/A	55	0	5	25	N/A
88092218	8	20.7N	127.9E	13.2	100.0	N/A	N/A	55	0	0	N/A	N/A
88092300	9	21.3N	127.3E	30.5	214.7	N/A	N/A	55	0	10	N/A	N/A
88092306	10	22.1N	126.8E	6.0	227.9	N/A	N/A	55	0	15	N/A	N/A
88092312	11	22.8N	126.4E	12.0	330.1	N/A	N/A	55	0	15	N/A	N/A
88092318	12	24.1N	126.6E	37.5	N/A	N/A	N/A	55	0	N/A	N/A	N/A
88092400	13	25.0N	127.7E	24.3	N/A	N/A	N/A	45	0	N/A	N/A	N/A
88092406	14	26.3N	128.8E	10.8	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88092412	15	27.4N	130.3E	18.8	N/A	N/A	N/A	40	-5	N/A	N/A	N/A

Tropical Storm Mamie (19W)

	00h	24h	48h	72h
Average	36	N/A	N/A	N/A
# Cases	4	0	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88092206	1	16.7N	112.5E	41.6	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88092212	2	17.9N	112.6E	36.5	N/A	N/A	N/A	45	-5	N/A	N/A	N/A
88092218	3	19.0N	113.1E	60.3	N/A	N/A	N/A	45	-5	N/A	N/A	N/A
88092300	4	19.7N	113.5E	8.2	N/A	N/A	N/A	45	-10	N/A	N/A	N/A

Super Typhoon Nelson (20W)

	00h	24h	48h	72h
Average	10	64	128	148
# Cases	30	26	22	18

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88100112	1	12.2N	136.1E	21.3	110.9	215.5	243.5	45	0	0	-25	-60
88100118	2	12.4N	135.0E	24.0	133.7	191.1	190.9	45	0	-5	-40	-60
88100200	3	12.8N	134.0E	5.9	122.1	211.6	191.4	45	0	-10	-40	-55
88100206	4	13.4N	133.0E	5.8	89.1	132.1	54.0	55	-5	-20	-50	-60
88100212	5	14.1N	131.8E	8.4	37.4	63.8	58.3	65	-10	-15	-50	-50
88100218	6	14.7N	130.6E	12.0	62.4	105.9	105.5	70	-10	-25	-50	-45
88100300	7	15.5N	129.4E	6.0	36.0	74.0	96.6	75	0	-25	-50	-45
88100306	8	16.1N	128.4E	8.3	61.6	56.0	107.1	90	-10	-35	-50	-45
88100312	9	16.8N	127.5E	8.3	41.2	81.9	127.8	100	-10	-35	-40	-35
88100318	10	17.5N	126.6E	8.3	17.9	78.8	168.0	115	-15	-20	-10	-15
88100400	11	18.5N	125.8E	13.3	22.4	84.2	168.1	120	-5	-5	0	0
88100406	12	19.3N	125.2E	5.7	110.8	143.1	144.1	130	-5	-5	-15	-25
88100412	13	20.0N	124.7E	5.6	30.0	123.9	162.9	140	0	-5	-5	-10
88100418	14	20.7N	124.4E	8.2	75.4	187.8	230.8	140	0	0	-10	-10
88100500	15	21.3N	124.4E	.0	68.1	172.9	99.4	140	0	-5	-15	5
88100506	16	21.9N	124.7E	8.2	71.9	141.6	197.2	140	0	0	-25	-5
88100512	17	22.5N	125.1E	11.1	76.1	101.9	141.2	140	-10	-15	-25	-15
88100518	18	23.3N	125.9E	12.0	99.7	150.0	180.6	130	-10	-25	-25	-25
88100600	19	24.0N	126.7E	11.0	60.9	82.9	N/A	125	-10	-15	-20	N/A
88100606	20	24.6N	127.7E	13.2	49.7	75.5	N/A	115	-5	-25	-20	N/A
88100612	21	25.3N	128.9E	6.0	81.9	231.5	N/A	115	-10	-10	-5	N/A
88100618	22	25.9N	130.0E	13.2	33.5	115.0	N/A	115	-15	-10	-5	N/A
88100700	23	26.6N	131.1E	.0	52.3	N/A	N/A	115	-15	5	N/A	N/A
88100706	24	27.6N	132.2E	8.0	41.4	N/A	N/A	115	-20	-15	N/A	N/A
88100712	25	28.5N	133.6E	8.0	24.5	N/A	N/A	100	-10	-5	N/A	N/A
88100718	26	29.5N	135.0E	10.4	56.5	N/A	N/A	90	0	-5	N/A	N/A
88100800	27	30.4N	136.5E	12.0	N/A	N/A	N/A	85	-5	N/A	N/A	N/A
88100806	28	31.4N	138.3E	15.8	N/A	N/A	N/A	75	-5	N/A	N/A	N/A
88100812	29	32.5N	140.6E	26.0	N/A	N/A	N/A	70	-5	N/A	N/A	N/A
88100818	30	33.6N	143.6E	23.3	N/A	N/A	N/A	70	-15	N/A	N/A	N/A

Typhoon Odessa (21W)

	00h	24h	48h	72h
Average	16	100	245	686
# Cases	22	18	10	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88101112	1	19.0N	132.5E	6.0	110.2	354.0	640.8	35	0	10	-5	-25
88101118	2	18.9N	131.3E	13.3	182.9	447.9	749.7	35	5	10	0	-25
88101200	3	18.9N	130.4E	6.0	191.3	475.2	778.0	40	5	20	25	0
88101206	4	19.2N	129.6E	21.3	243.1	545.6	853.1	45	0	-10	-10	-25
88101212	5	19.8N	129.4E	.0	57.4	216.0	408.6	45	0	-10	-25	-25
88101218	6	20.5N	129.2E	12.7	17.7	N/A	N/A	45	-5	-35	N/A	N/A
88101300	7	21.1N	129.0E	13.2	190.7	N/A	N/A	45	-5	-40	N/A	N/A
88101306	8	21.6N	128.9E	5.6	39.1	48.6	N/A	65	5	-25	-60	N/A
88101312	9	21.9N	129.2E	11.1	56.3	N/A	N/A	65	0	-45	N/A	N/A

88101318	10	22.1N	129.5E	11.1	81.4	N/A	N/A	65	0	-45	N/A	N/A
88101400	11	22.4N	130.0E	5.5	60.0	58.2	N/A	65	5	-40	-55	N/A
88101406	12	23.0N	130.5E	.0	42.0	88.0	N/A	75	-5	-35	-30	N/A
88101412	13	23.6N	130.9E	8.1	37.6	91.4	N/A	90	-10	5	15	N/A
88101418	14	24.2N	131.3E	.0	17.3	132.0	N/A	90	0	20	45	N/A
88101500	15	24.7N	131.8E	.0	36.9	N/A	N/A	90	0	0	N/A	N/A
88101506	16	25.2N	132.4E	5.4	93.6	N/A	N/A	90	0	5	N/A	N/A
88101512	17	25.6N	132.9E	8.1	159.3	N/A	N/A	90	0	15	N/A	N/A
88101518	18	25.8N	133.3E	.0	191.4	N/A	N/A	90	-5	20	N/A	N/A
88101600	19	26.1N	133.4E	22.4	N/A	N/A	N/A	85	0	N/A	N/A	N/A
88101606	20	26.3N	133.1E	74.0	N/A	N/A	N/A	75	0	N/A	N/A	N/A
88101612	21	26.4N	132.8E	117.0	N/A	N/A	N/A	65	-10	N/A	N/A	N/A
88101618	22	26.5N	132.4E	16.1	N/A	N/A	N/A	55	-20	N/A	N/A	N/A

Typhoon Pat (22W)

	00h	24h	48h	72h
Average	17	140	303	436
# Cases	17	13	9	5

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88101818	1	15.6N	133.2E	6.0	99.6	297.7	498.7	35	0	0	5	35
88101900	2	16.2N	131.8E	8.3	139.7	323.9	457.2	40	5	0	25	35
88101906	3	16.5N	130.6E	6.0	149.9	365.4	502.5	45	0	-10	25	45
88101912	4	16.5N	129.3E	23.8	152.7	367.7	402.3	50	0	-10	10	40
88101918	5	16.4N	127.8E	12.0	129.4	268.8	320.1	55	0	-5	25	55
88102000	6	16.3N	126.1E	5.8	92.0	229.3	N/A	65	0	-10	0	N/A
88102006	7	16.3N	124.6E	8.3	185.4	299.4	N/A	75	0	10	20	N/A
88102012	8	16.4N	123.1E	13.0	215.2	319.4	N/A	75	15	10	35	N/A
88102018	9	16.5N	120.9E	6.0	132.7	262.9	N/A	70	-15	0	30	N/A
88102100	10	16.6N	118.5E	29.4	133.8	N/A	N/A	65	0	20	N/A	N/A
88102106	11	17.0N	116.5E	26.6	146.4	N/A	N/A	65	0	20	N/A	N/A
88102112	12	17.4N	114.7E	18.9	99.2	N/A	N/A	65	0	10	N/A	N/A
88102118	13	17.8N	113.2E	21.3	145.0	N/A	N/A	65	0	0	N/A	N/A
88102200	14	18.2N	111.6E	23.6	N/A	N/A	N/A	65	0	N/A	N/A	N/A
88102206	15	18.6N	110.1E	16.5	N/A	N/A	N/A	60	0	N/A	N/A	N/A
88102212	16	19.2N	108.6E	26.5	N/A	N/A	N/A	55	-5	N/A	N/A	N/A
88102218	17	20.0N	107.4E	41.1	N/A	N/A	N/A	45	0	N/A	N/A	N/A

Typhoon Ruby (23W)

	00h	24h	48h	72h
Average	28	113	163	210
# Cases	30	26	22	18

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88102112	1	9.9N	135.9E	56.1	102.2	34.8	203.2	35	0	-5	-15	-65
88102118	2	9.7N	135.4E	93.9	152.0	39.5	168.0	40	-5	-10	-20	-65
88102200	3	9.5N	134.8E	16.9	110.5	287.9	425.4	45	-5	-15	-25	0
88102206	4	9.5N	134.1E	18.0	109.4	230.5	326.8	50	0	10	0	40
88102212	5	9.6N	133.2E	11.8	133.1	276.5	288.2	60	-5	-15	-20	40
88102218	6	10.0N	132.2E	8.4	92.9	181.4	143.8	65	0	-5	-20	45
88102300	7	10.7N	131.0E	29.5	164.3	230.0	161.6	70	0	-10	10	20
88102306	8	11.1N	129.6E	21.5	106.3	237.8	283.7	80	-5	-10	15	10
88102312	9	11.5N	128.2E	6.0	82.7	145.7	71.0	90	0	-20	20	25
88102318	10	12.2N	126.7E	24.7	90.9	99.0	70.9	95	0	-30	10	20
88102400	11	12.9N	125.4E	25.1	93.8	64.4	69.7	100	-5	-10	25	40
88102406	12	13.8N	124.1E	13.3	24.9	102.2	132.7	110	-10	45	55	65
88102412	13	14.6N	122.8E	8.3	119.1	231.4	360.6	125	0	35	45	-20
88102418	14	15.2N	121.7E	8.3	120.5	174.0	278.1	120	0	25	35	5
88102500	15	16.0N	120.4E	8.3	114.6	190.2	352.7	90	0	35	40	10
88102506	16	16.2N	118.9E	5.8	116.7	138.1	291.1	70	-5	10	15	10
88102512	17	16.4N	118.0E	31.2	132.0	94.3	75.3	65	5	10	20	30
88102518	18	16.5N	117.6E	37.8	109.6	119.6	81.9	65	5	15	40	40

88102600	19	16.5N	117.1E	36.0	130.6	164.8	N/A	65	5	15	35	N/A
88102606	20	16.8N	116.6E	29.6	141.2	164.8	N/A	65	0	0	15	N/A
88102612	21	17.2N	115.8E	50.1	131.5	176.5	N/A	65	0	5	20	N/A
88102618	22	17.6N	115.0E	22.9	77.0	222.5	N/A	65	-5	0	15	N/A
88102700	23	17.9N	114.3E	58.1	256.1	N/A	N/A	60	0	-15	N/A	N/A
88102706	24	18.2N	113.3E	18.0	51.1	N/A	N/A	60	0	5	N/A	N/A
88102712	25	18.4N	112.5E	16.5	87.0	N/A	N/A	55	0	5	N/A	N/A
88102718	26	18.5N	111.7E	18.0	108.7	N/A	N/A	50	0	10	N/A	N/A
88102800	27	18.8N	110.9E	20.8	N/A	N/A	N/A	45	0	N/A	N/A	N/A
88102806	28	18.7N	110.1E	36.1	N/A	N/A	N/A	35	5	N/A	N/A	N/A
88102812	29	18.4N	109.3E	54.3	N/A	N/A	N/A	30	5	N/A	N/A	N/A
88102818	30	18.2N	108.5E	79.8	N/A	N/A	N/A	25	5	N/A	N/A	N/A

Typhoon Skip (24W)

	00h	24h	48h	72h
Average	18	99	199	260
# Cases	30	29	21	17

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88110318	1	9.1N	139.4E	18.8	145.8	303.9	419.3	35	0	-20	-30	-20
88110400	2	9.0N	139.0E	21.4	126.6	270.2	394.7	45	0	-25	-25	-10
88110406	3	8.9N	138.4E	36.1	148.1	269.5	371.9	55	-5	-20	-25	20
88110412	4	8.8N	137.7E	13.4	77.2	166.4	294.9	65	0	-10	-15	-10
88110418	5	8.8N	136.8E	11.9	97.5	189.2	305.4	75	0	-5	-5	-5
88110500	6	8.9N	135.7E	12.0	21.4	100.5	287.6	90	5	0	5	20
88110506	7	9.1N	134.6E	.0	86.1	230.0	443.7	95	0	-20	5	15
88110512	8	9.3N	133.3E	8.4	51.0	176.2	359.8	100	0	-5	25	35
88110518	9	9.4N	132.2E	13.3	35.9	213.8	285.0	105	-5	-5	5	10
88110600	10	9.6N	131.0E	13.4	69.2	233.3	239.6	115	0	10	15	20
88110606	11	9.8N	129.9E	8.4	77.4	181.4	247.2	125	0	30	15	25
88110612	12	10.2N	128.6E	.0	67.9	174.4	116.5	125	0	0	-20	-20
88110618	13	10.4N	127.3E	11.8	95.0	134.0	68.1	120	5	-15	-25	-20
88110700	14	10.8N	126.0E	.0	126.5	123.4	36.0	120	5	25	20	0
88110706	15	11.4N	124.5E	24.3	166.1	164.2	210.4	105	15	10	15	40
88110712	16	12.3N	122.8E	21.3	133.0	138.1	197.1	100	15	15	20	55
88110718	17	12.8N	120.7E	31.6	50.6	54.3	154.3	95	20	20	30	75
88110800	18	13.1N	119.1E	29.5	180.5	407.4	N/A	90	10	10	-45	N/A
88110806	19	13.3N	117.8E	37.8	145.1	N/A	N/A	90	0	-5	N/A	N/A
88110812	20	13.7N	116.7E	35.5	165.1	N/A	N/A	90	-5	-25	N/A	N/A
88110818	21	14.1N	115.8E	35.4	152.7	N/A	N/A	90	-5	-25	N/A	N/A
88110900	22	14.5N	115.0E	6.0	92.7	203.4	N/A	85	0	-5	5	N/A
88110906	23	14.9N	114.3E	11.6	132.0	252.5	N/A	85	0	0	-10	N/A
88110912	24	15.2N	113.7E	5.8	88.5	215.4	N/A	90	0	10	-10	N/A
88110918	25	15.3N	113.2E	23.9	116.3	N/A	N/A	90	0	10	N/A	N/A
88111000	26	15.4N	112.9E	34.7	109.9	N/A	N/A	90	-10	10	N/A	N/A
88111006	27	15.5N	112.6E	13.0	.0	N/A	N/A	75	-10	0	N/A	N/A
88111012	28	15.5N	112.3E	18.9	99.9	N/A	N/A	65	0	5	N/A	N/A
88111018	29	15.6N	111.8E	21.1	26.6	N/A	N/A	55	5	0	N/A	N/A
88111100	30	15.7N	111.3E	31.3	N/A	N/A	N/A	45	-10	N/A	N/A	N/A

Typhoon Tess (25W)

	00h	24h	48h	72h
Average	14	57	123	N/A
# Cases	10	8	4	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88110400	1	9.2N	119.3E	18.8	59.7	183.0	N/A	30	0	-20	-25	N/A
88110406	2	9.3N	118.5E	23.7	87.7	181.9	N/A	35	0	-5	0	N/A
88110412	3	9.4N	117.5E	11.8	63.2	85.5	N/A	35	0	-20	10	N/A
88110418	4	9.6N	116.6E	5.9	18.9	43.0	N/A	40	0	-10	0	N/A
88110500	5	9.7N	115.8E	6.0	72.4	N/A	N/A	55	0	5	N/A	N/A
88110506	6	9.8N	114.5E	29.6	119.6	N/A	N/A	50	5	15	N/A	N/A

88110512	7	10.2N	113.3E	8.4	25.2	N/A	N/A	65	0	30	N/A	N/A
88110518	8	10.5N	112.3E	13.4	13.2	N/A	N/A	65	0	15	N/A	N/A
88110600	9	10.8N	111.2E	8.4	N/A	N/A	N/A	65	0	N/A	N/A	N/A
88110606	10	11.0N	110.2E	21.5	N/A	N/A	N/A	55	0	N/A	N/A	N/A

Tropical Storm Val (26W)

	00h	24h	48h	72h
Average	57	228	768	N/A
# Cases	10	6	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 WE	48 WE	72 WE
88122218	1	11.9N	129.5E	21.5	128.9	N/A	N/A	30	0	0	N/A	N/A
88122300	2	13.0N	127.6E	67.8	390.5	767.9	N/A	30	5	-25	-10	N/A
88122306	3	13.8N	126.2E	42.9	367.7	N/A	N/A	35	0	-25	N/A	N/A
88122312	4	14.3N	125.7E	8.4	186.3	N/A	N/A	40	-5	-15	N/A	N/A
88122318	5	14.6N	125.3E	6.0	107.0	N/A	N/A	45	5	25	N/A	N/A
88122400	6	14.7N	125.0E	47.9	187.7	N/A	N/A	55	0	-5	N/A	N/A
88122406	7	14.8N	124.7E	90.2	N/A	N/A	N/A	55	0	N/A	N/A	N/A
88122412	8	14.9N	124.5E	93.5	N/A	N/A	N/A	50	0	N/A	N/A	N/A
88122418	9	14.9N	124.4E	88.8	N/A	N/A	N/A	45	0	N/A	N/A	N/A
88122500	10	15.0N	124.3E	108.3	N/A	N/A	N/A	40	0	N/A	N/A	N/A

b. NORTH INDIAN OCEAN

This section includes verification statistics for each warning in the North Indian Ocean during 1988. Pre- and post- warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

Tropical Cyclone 01A

	00h	24h	48h	72h
Average	61	188	484	N/A
# Cases	10	6	2	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
88061000	1	16.9N	69.4E	183.8	360.8	577.5	N/A	35	0	-10	-10	N/A
88061006	2	16.8N	69.0E	86.4	253.1	N/A	N/A	35	0	-10	N/A	N/A
88061012	3	16.6N	68.6E	81.3	210.2	N/A	N/A	35	0	-10	N/A	N/A
88061018	4	16.3N	68.7E	84.0	251.7	390.1	N/A	35	0	-10	-5	N/A
88061100	5	16.2N	69.0E	29.2	29.2	N/A	N/A	35	0	-10	N/A	N/A
88061106	6	16.1N	69.5E	33.3	23.8	N/A	N/A	35	0	0	N/A	N/A
88061112	7	16.2N	69.8E	29.2	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88061118	8	16.3N	70.2E	26.6	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88061200	9	16.4N	70.4E	34.0	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88061206	10	16.6N	70.7E	31.1	N/A	N/A	N/A	25	10	N/A	N/A	N/A

Tropical Cyclone 02B

	00h	24h	48h	72h
Average	30	N/A	N/A	N/A
# Cases	3	0	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
88101812	1	19.6N	91.3E	25.6	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88101818	2	20.8N	90.6E	13.2	N/A	N/A	N/A	30	5	N/A	N/A	N/A
88101900	3	22.2N	89.9E	53.1	N/A	N/A	N/A	30	5	N/A	N/A	N/A

Tropical Cyclone 03B

	00h	24h	48h	72h
Average	28	N/A	N/A	N/A
# Cases	3	0	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
88111800	1	17.7N	90.9E	17.1	N/A	N/A	N/A	40	0	N/A	N/A	N/A
88111806	2	18.7N	91.7E	34.5	N/A	N/A	N/A	50	0	N/A	N/A	N/A
88111812	3	19.7N	93.0E	33.5	N/A	N/A	N/A	55	0	N/A	N/A	N/A

Tropical Cyclone 04B

	00h	24h	48h	72h
Average	22	90	186	409
# Cases	22	20	16	12

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WN ER	24 ER	48 ER	72 ER
88112406	1	10.0N	93.6E	56.1	123.8	196.1	374.7	35	0	5	-5	0
88112412	2	10.4N	93.1E	.0	59.6	114.6	229.4	40	-5	-15	-25	-25
88112418	3	10.7N	92.6E	5.9	72.0	118.8	209.2	45	-5	-15	-20	-20
88112500	4	11.0N	92.0E	26.7	18.9	75.9	193.5	50	-5	-10	-10	-25
88112506	5	11.1N	91.4E	13.4	51.2	75.8	216.9	50	0	-5	-5	-15
88112512	6	11.1N	90.7E	8.4	48.5	212.7	387.3	55	0	-10	0	0
88112518	7	11.2N	90.1E	5.9	84.1	234.9	439.2	60	5	0	5	-30
88112600	8	11.3N	89.5E	11.8	113.4	270.7	511.7	65	10	20	15	-20
88112606	9	11.6N	89.0E	35.8	144.8	301.8	552.5	70	5	10	5	-40
88112612	10	12.1N	88.5E	25.2	130.0	292.4	630.6	75	0	10	10	-75

88112618	11	12.7N	88.3E	46.4	133.8	307.3	663.2	75	0	10	5	-60
88112700	12	13.2N	88.1E	30.0	56.7	216.4	508.8	75	5	5	0	20
88112706	13	13.7N	88.0E	13.3	25.0	96.3	N/A	75	0	-15	-45	N/A
88112712	14	14.2N	87.9E	29.4	44.1	151.7	N/A	80	-5	-20	-55	N/A
88112718	15	14.7N	87.7E	35.3	41.8	147.8	N/A	85	0	-10	-30	N/A
88112800	16	15.3N	87.7E	36.7	69.0	168.4	N/A	90	0	-15	0	N/A
88112806	17	15.8N	87.7E	8.3	115.3	N/A	N/A	90	0	-15	N/A	N/A
88112812	18	16.6N	87.8E	29.6	196.0	N/A	N/A	90	0	-30	N/A	N/A
88112818	19	17.7N	88.0E	51.0	181.1	N/A	N/A	95	-5	-20	N/A	N/A
88112900	20	19.0N	88.1E	18.0	101.6	N/A	N/A	100	0	5	N/A	N/A
88112906	21	20.4N	88.3E	12.8	N/A	N/A	N/A	105	5	N/A	N/A	N/A
88112912	22	21.8N	89.0E	6.0	N/A	N/A	N/A	110	-25	N/A	N/A	N/A

Tropical Cyclone 05B

	00h	24h	48h	72h
Average	37	171	N/A	N/A
# Cases	6	4	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	72 ER	BT WN	WW ER	24 ER	48 ER	72 ER
88120700	1	9.7N	89.7E	18.9	211.7	N/A	N/A	35	10	30	N/A	N/A
88120706	2	10.3N	89.8E	33.7	234.5	N/A	N/A	40	5	30	N/A	N/A
88120712	3	10.8N	90.5E	47.2	168.4	N/A	N/A	45	-5	20	N/A	N/A
88120718	4	11.0N	91.4E	60.1	72.5	N/A	N/A	40	-5	15	N/A	N/A
88120800	5	11.1N	92.3E	42.9	N/A	N/A	N/A	35	0	N/A	N/A	N/A
88120806	6	11.7N	92.7E	24.0	N/A	N/A	N/A	35	0	N/A	N/A	N/A

c. SOUTHERN HEMISPHERE

This section includes verification statistics for each warning in the South Indian and western South Pacific Oceans from 1 July 1987 to 30 June 1988. Pre- and post- warning best track positions are not printed, but are available on floppy diskettes by request.

JTWC FORECAST TRACK AND INTENSITY ERRORS BY WARNING

Tropical Cyclone 01S

	00h	24h	48h
Average	33	124	216
# Cases	20	18	15

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 ER	48 ER
87110118	1	5.6S	79.9E	18.9	80.4	233.8	35	0	10	25
87110206	2	5.9S	77.5E	21.6	114.2	212.4	35	0	10	30
87110218	3	6.4S	75.8E	49.2	184.4	381.0	45	0	20	45
87110300*	4	6.6S	75.1E	77.7	237.8	421.4	45	5	30	40
87110306	5	6.9S	74.5E	41.7	176.8	343.6	45	0	20	25
87110312*	6	7.2S	73.8E	32.1	168.5	263.9	45	0	20	25
87110318	7	7.6S	73.4E	24.7	144.7	162.4	45	0	20	25
87110400*	8	8.0S	73.0E	37.9	127.0	134.2	40	5	0	-5
87110406	9	9.6S	72.6E	62.6	112.0	129.1	40	0	-10	-10
87110418	10	10.0S	71.9E	39.7	198.4	N/A	40	-5	-15	N/A
87110506	11	10.4S	70.7E	36.5	36.5	195.1	45	-5	5	0
87110518	12	10.8S	69.8E	32.2	74.9	109.1	45	-5	-10	-15
87110606	13	11.4S	68.8E	8.4	29.9	42.6	45	0	-20	-15
87110618	14	11.8S	68.0E	30.0	66.7	204.4	50	-5	-15	-5
87110706	15	12.2S	67.1E	5.9	52.6	189.5	55	-5	0	0
87110718	16	12.8S	66.0E	17.6	108.9	218.9	50	0	5	0
87110806	17	12.9S	64.6E	47.4	171.0	N/A	45	0	5	N/A
87110818	18	12.5S	63.2E	60.6	102.2	N/A	35	10	0	N/A
87110906	19	11.9S	62.3E	6.0	N/A	N/A	35	0	N/A	N/A
87110918	20	11.7S	61.3E	16.8	N/A	N/A	35	-5	N/A	N/A

* Six hourly warnings were issued due to systems proximity to Diego Garcia.

Tropical Cyclone 02S

	00h	24h	48h
Average	20	57	N/A
# Cases	5	1	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
87112406	1	10.7S	41.5E	16.8	N/A	N/A	35	0	N/A	N/A
87112418	2	11.5S	41.1E	26.7	56.8	N/A	40	5	10	N/A
87112506	3	12.2S	40.6E	.0	N/A	N/A	35	0	N/A	N/A
87112518	4	13.2S	40.0E	46.2	N/A	N/A	25	5	N/A	N/A
87112606	5	14.5S	39.6E	13.3	N/A	N/A	20	5	N/A	N/A

Tropical Cyclone 03S

	00h	24h	48h
Average	34	127	272
# Cases	10	7	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
87120918	1	12.3S	87.9E	17.6	60.3	167.1	35	5	10	15
87121006	2	13.1S	85.9E	11.7	164.3	213.1	40	0	-5	10
87121018	3	14.6S	84.8E	24.0	172.5	270.7	50	0	5	15
87121106	4	16.1S	84.4E	35.1	91.0	203.7	55	5	15	10
87121118	5	16.8S	84.0E	16.6	70.7	299.0	55	10	5	5
87121206	6	17.8S	83.1E	12.9	140.6	481.2	55	0	-10	0
87121218	7	18.5S	82.3E	18.9	192.9	N/A	55	-10	-15	N/A
87121306	8	17.8S	81.2E	91.0	N/A	N/A	55	-15	N/A	N/A

87121318	9	17.1S	79.3E	87.9	N/A	N/A	45	-10	N/A	N/A
87121406	10	17.1S	76.5E	24.7	N/A	N/A	35	-10	N/A	N/A

Tropical Cyclone 04P

	00h	24h	48h
Average	58	N/A	N/A
# Cases	2	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
87122200	1	13.8S	179.3E	80.7	N/A	N/A	30	0	N/A	N/A
87122212	2	15.2S	180.8E	36.0	N/A	N/A	25	5	N/A	N/A

Tropical Cyclone 05S

	00h	24h	48h
Average	39	158	517
# Cases	11	9	1

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
87122700	1	13.9S	70.1E	33.4	288.2	516.6	35	0	0	-5
87122718	2	13.4S	67.8E	29.8	264.3	N/A	35	0	-5	N/A
87122806	3	13.7S	65.6E	55.4	244.6	N/A	35	0	-5	N/A
87122818	4	13.2S	63.1E	50.2	96.0	N/A	35	0	-5	N/A
87122906	5	12.8S	60.9E	42.9	48.0	N/A	35	0	-5	N/A
87122918	6	13.4S	59.2E	12.0	46.8	N/A	35	0	-5	N/A
87123006	7	14.6S	57.7E	35.4	169.1	N/A	35	0	0	N/A
87123018	8	14.9S	56.2E	6.0	122.0	N/A	35	0	0	N/A
87123106	9	15.5S	55.8E	46.3	144.6	N/A	30	5	5	N/A
87123118	10	15.9S	55.3E	88.7	N/A	N/A	30	0	N/A	N/A
88010106	11	15.2S	51.3E	29.6	N/A	N/A	25	0	N/A	N/A

Tropical Cyclone 06P

	00h	24h	48h
Average	62	242	432
# Cases	16	11	6

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88010606	1	17.1S	161.2E	5.7	90.8	312.2	35	0	20	5
88010618	2	17.1S	159.8E	71.0	313.6	480.7	35	0	10	0
88010706	3	16.4S	158.3E	42.4	N/A	N/A	25	0	N/A	N/A
88010900*	4	13.4S	156.1E	74.0	131.0	336.6	30	5	20	25
88010906	5	13.2S	155.8E	98.1	177.2	298.8	35	0	10	5
88010918	6	12.8S	155.0E	85.8	201.5	N/A	35	0	-10	N/A
88011006	7	11.8S	154.5E	171.9	N/A	N/A	35	0	N/A	N/A
88011018	8	11.0S	154.6E	85.4	136.7	266.0	40	15	35	35
88011106	9	10.7S	154.3E	16.8	N/A	N/A	45	-5	N/A	N/A
88011118	10	10.8S	153.8E	53.5	34.7	N/A	50	-10	-20	N/A
88011206	11	11.1S	153.1E	18.9	314.7	900.8	55	0	-20	-20
88011218	12	13.1S	154.0E	47.1	402.3	N/A	55	0	-30	N/A
88011306	13	15.0S	155.4E	128.1	630.7	N/A	60	-5	-5	N/A
88011318	14	17.2S	158.7E	21.3	230.1	N/A	70	0	35	N/A
88011406	15	20.0S	163.4E	86.9	N/A	N/A	50	25	N/A	N/A
88011418	16	23.1S	167.4E	.0	N/A	N/A	30	-5	N/A	N/A

* regenerated

Tropical Cyclone 07P

	00h	24h	48h
Average	24	112	198
# Cases	14	12	10

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88010712	1	5.8S	177.8E	26.7	130.9	212.7	35	0	5	-5
88010800	2	6.8S	176.0E	18.9	56.1	138.7	35	5	5	-25
88010812	3	7.7S	174.2E	71.6	201.2	216.3	45	5	0	-40
88010900	4	9.0S	172.9E	54.3	205.5	399.5	50	5	-20	-60
88010912	5	10.0S	171.1E	8.4	90.8	138.5	65	-5	-40	-45
88011000	6	11.4S	169.1E	11.8	68.3	41.4	90	-5	-35	0
88011012	7	13.0S	167.1E	8.4	49.4	147.7	115	5	5	55
88011100	8	15.0S	165.4E	18.9	111.5	210.5	140	-5	30	65
88011112	9	16.8S	164.3E	12.0	168.3	306.2	130	0	25	45
88011200	10	18.5S	164.3E	23.5	137.3	170.0	115	0	35	45
88011212	11	20.1S	165.2E	6.0	48.9	N/A	85	5	15	N/A
88011300	12	21.7S	165.8E	46.2	86.8	N/A	60	5	15	N/A
88011312	13	23.4S	167.2E	30.1	N/A	N/A	45	5	N/A	N/A
88011400	14	25.2S	170.1E	8.1	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 08S

	00h	24h	48h
Average	15	60	75
# Cases	5	2	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88011312	1	13.3S	53.8E	13.3	70.4	80.3	35	5	0	10
88011400	2	14.4S	52.3E	31.4	50.3	69.6	45	-10	-20	5
88011412	3	15.6S	50.9E	13.3	N/A	N/A	55	0	N/A	N/A
88011500	4	16.3S	50.2E	8.3	N/A	N/A	65	0	N/A	N/A
88011512	5	17.1S	49.3E	12.9	N/A	N/A	40	0	N/A	N/A

Tropical Cyclone 09S

	00h	24h	48h
Average	36	115	232
# Cases	17	12	9

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88012306	1	12.7S	66.9E	47.2	218.1	338.2	35	0	0	10
88012318	2	13.0S	62.5E	16.8	109.3	228.8	40	5	10	35
88012406	3	13.6S	58.9E	18.0	66.3	220.9	50	5	15	0
88012418	4	14.2S	55.3E	13.1	113.6	N/A	55	0	0	N/A
88012506	5	14.8S	52.4E	26.1	N/A	N/A	55	0	N/A	N/A
88012518	6	14.7S	50.6E	56.1	N/A	N/A	45	5	N/A	N/A
88012606	7	14.2S	49.3E	133.2	N/A	N/A	30	0	N/A	N/A
88012800*	8	17.2S	43.0E	.0	41.5	90.7	45	-10	-20	-50
88012812	9	18.7S	41.6E	70.7	173.7	311.9	55	-15	-40	-90
88012900	10	20.2S	40.8E	46.6	161.2	240.2	65	0	-25	-55
88012912	11	21.2S	39.8E	29.3	12.5	113.3	75	5	-50	-45
88013000	12	22.3S	38.9E	24.0	60.2	223.6	90	0	-30	-10
88013012	13	24.1S	38.3E	31.9	112.6	326.3	115	-25	-25	20
88013100	14	26.3S	38.2E	21.0	139.2	N/A	115	-15	10	N/A
88013112	15	28.8S	38.9E	21.9	176.8	N/A	105	-15	35	N/A
88020100	16	31.5S	41.2E	35.6	N/A	N/A	85	-5	N/A	N/A
88020112	17	34.6S	44.8E	30.2	N/A	N/A	45	15	N/A	N/A

* regenerated

Tropical Cyclone 10S

	00h	24h	48h
Average	24	178	430
# Cases	6	4	2

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88013100	1	13.6S	96.6E	18.5	166.6	359.1	35	0	-10	20
88013106	2	14.8S	96.5E	21.1	130.9	500.9	40	5	10	30
88013118	3	17.1S	95.9E	12.9	122.0	N/A	50	25	30	N/A
88020106	4	19.1S	96.0E	8.3	294.5	N/A	55	20	30	N/A
88020118	5	20.6S	95.5E	17.9	N/A	N/A	45	5	N/A	N/A
88020206	6	21.2S	93.9E	70.2	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 11S

	00h	24h	48h
Average	25	133	282
# Cases	16	14	11

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88020812	1	15.8S	101.1E	63.1	302.8	568.1	30	5	10	-5
88020900	2	16.0S	99.1E	50.9	194.2	439.8	35	0	0	-35
88020912	3	15.9S	97.2E	28.9	110.4	196.0	40	-5	-30	-55
88021000	4	15.8S	95.0E	23.9	115.5	271.0	45	-5	-30	-55
88021012	5	15.6S	93.4E	16.7	156.2	322.0	60	-10	-20	-10
88021100	6	15.7S	91.9E	40.9	173.4	287.4	70	-10	-35	-15
88021112	7	16.1S	90.8E	16.6	93.1	143.5	80	-20	-20	-15
88021200	8	17.1S	90.1E	8.3	123.4	379.2	90	-25	-10	0
88021212	9	17.8S	89.3E	36.3	107.6	309.3	80	-15	5	10
88021300	10	18.4S	88.5E	24.7	36.0	37.2	70	-15	-5	-10
88021312	11	18.6S	87.8E	28.4	40.2	N/A	60	-10	-10	N/A
88021400	12	19.1S	86.5E	16.5	198.6	N/A	50	0	-15	N/A
88021412	13	18.8S	85.0E	11.4	98.4	156.0	45	10	5	0
88021500	14	18.6S	83.9E	17.1	114.6	N/A	45	0	-5	N/A
88021512	15	18.2S	82.6E	16.6	N/A	N/A	40	-5	N/A	N/A
88021600	16	18.2S	80.9E	8.3	N/A	N/A	35	-5	N/A	N/A

Tropical Cyclone 12P

	00h	24h	48h
Average	30	133	261
# Cases	12	8	7

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88022100	1	13.7S	158.4E	53.8	255.7	419.4	35	0	5	5
88022106	2	13.9S	158.0E	46.6	202.1	406.4	35	0	-5	-5
88022118	3	14.3S	157.4E	96.2	238.9	197.7	35	0	0	0
88022206	4	14.6S	156.8E	16.7	63.4	77.4	40	0	0	10
88022218	5	14.6S	156.0E	52.3	615.2	179.1	40	0	-10	5
88022306	6	14.6S	155.2E	6.0	79.2	200.1	45	0	15	30
88022318	7	14.8S	164.5E	586.0	143.0	158.3	45	0	15	10
88022406	8	15.5S	154.6E	8.3	49.4	N/A	40	5	10	N/A
88022418	9	16.6S	155.0E	33.9	N/A	N/A	30	0	N/A	N/A
88022806	10	19.0S	148.3E	28.4	N/A	N/A	35	5	N/A	N/A
88022818	11	18.9S	147.7E	6.0	N/A	N/A	35	0	N/A	N/A
88022906	12	19.3S	147.2E	13.3	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 13P

	00h	24h	48h
Average	25	167	337
# Cases	20	16	15

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88022400	1	11.6S	178.6E	31.7	149.0	432.1	30	10	20	5
88022412	2	13.9S	177.2E	29.7	N/A	N/A	35	0	N/A	N/A
88022500	3	15.2S	177.0E	42.8	270.2	442.8	35	10	-5	-10
88022512	4	15.6S	176.0E	37.9	317.2	358.9	45	0	-10	-10
88022600	5	15.1S	173.8E	37.6	126.4	170.4	50	5	10	5
88022612	6	14.5S	171.4E	5.8	220.1	310.6	55	0	0	-35
88022700	7	15.3S	170.7E	16.7	86.6	214.3	55	0	-20	-60
88022712	8	16.2S	170.1E	24.9	114.8	190.5	55	0	-35	-60
88022800	9	16.4S	169.2E	34.5	124.3	287.6	60	-5	-45	-55
88022812	10	16.6S	168.3E	31.1	207.2	298.4	80	-5	0	0
88022900	11	16.8S	168.3E	5.7	165.7	228.6	90	0	-5	-20
88022912	12	17.3S	169.5E	5.7	69.0	162.2	95	0	-5	10
88030100	13	18.1S	169.7E	23.6	140.9	347.5	95	5	5	15
88030112	14	18.0S	169.0E	12.9	143.2	476.2	105	5	30	35
88030200	15	17.7S	169.2E	13.3	108.3	518.8	95	5	15	15
88030212	16	17.7S	169.8E	16.6	277.1	616.7	80	0	0	5
88030300	17	18.2S	171.2E	8.3	156.5	N/A	70	-5	-15	N/A
88030312	18	19.5S	174.3E	12.8	N/A	N/A	60	0	N/A	N/A
88030400	19	22.7S	177.3E	6.0	N/A	N/A	55	0	N/A	N/A
88030412	20	26.0S	178.6E	113.8	N/A	N/A	45	0	N/A	N/A

Tropical Cyclone 14S

	00h	24h	48h
Average	21	111	269
# Cases	8	6	4

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88022718	1	17.9S	41.1E	12.9	51.3	196.1	40	-5	-20	-40
88022806	2	18.8S	40.0E	22.7	159.3	270.3	55	0	-5	-30
88022818	3	19.1S	40.0E	8.3	90.7	266.6	65	0	-5	-5
88022906	4	19.3S	39.8E	12.0	111.4	342.8	75	0	10	45
88022918	5	19.2S	39.5E	29.4	185.4	N/A	80	10	15	N/A
88030106	6	18.9S	38.5E	20.8	69.7	N/A	85	-10	0	N/A
88030118	7	18.6S	37.1E	20.9	N/A	N/A	85	-25	N/A	N/A
88030206	8	17.7S	36.0E	42.0	N/A	N/A	40	-5	N/A	N/A

Tropical Cyclone 15P

	00h	24h	48h
Average	58	158	558
# Cases	8	5	4

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88022818	1	16.9S	201.2E	56.7	95.1	349.5	25	10	20	20
88022906	2	19.2S	201.1E	66.1	259.8	563.9	30	5	0	5
88022918	3	20.5S	204.2E	39.3	94.6	404.8	35	10	-10	5
88030106	4	22.7S	207.3E	20.5	227.9	913.4	40	5	10	15
88030118	5	25.4S	210.3E	17.3	114.5	N/A	45	5	10	N/A
88030206	6	28.1S	212.9E	28.8	N/A	N/A	35	5	N/A	N/A
88030218	7	31.2S	212.1E	57.8	N/A	N/A	25	15	N/A	N/A
88030306	8	34.2S	209.7E	177.9	N/A	N/A	25	5	N/A	N/A

Tropical Cyclone 16S

	00h	24h	48h
Average	31	168	298
# Cases	16	14	13

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88031600	1	14.6S	71.0E	13.3	177.7	284.7	35	0	15	5
88031612	2	14.3S	68.8E	55.2	138.6	244.5	40	0	0	-25
88031700	3	14.0S	66.8E	37.8	25.0	80.6	50	0	-5	-35
88031712	4	14.5S	65.2E	5.8	79.7	276.9	65	0	-30	-30
88031800	5	15.1S	64.0E	24.7	74.1	309.0	85	-10	-35	-25
88031812	6	15.8S	63.2E	21.1	142.1	477.7	115	-15	-25	-15
88031900	7	16.3S	63.0E	23.8	260.4	301.9	130	0	5	-15
88031912	8	16.5S	64.2E	37.5	286.8	342.5	125	0	0	0
88032000	9	16.7S	66.6E	13.3	187.0	433.6	115	0	-5	-5
88032012	10	17.9S	68.9E	21.3	141.0	325.4	105	0	0	5
88032100	11	20.0S	70.5E	46.6	200.7	177.1	95	0	-5	10
88032112	12	21.8S	70.9E	83.4	231.2	187.9	80	0	5	5
88032200	13	22.6S	70.8E	30.0	191.1	442.2	70	-10	5	5
88032212	14	24.2S	71.4E	27.4	218.0	N/A	50	0	10	N/A
88032300	15	27.0S	72.9E	12.3	N/A	N/A	40	0	N/A	N/A
88032312	16	29.7S	74.3E	54.2	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 17S

	00h	24h	48h
Average	20	204	375
# Cases	7	5	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88031718	1	11.0S	50.9E	21.5	300.7	578.7	35	0	15	35
88031806	2	10.1S	51.0E	13.3	150.6	262.3	40	0	10	35
88031818	3	10.2S	52.2E	16.8	199.4	283.5	40	0	10	40
88031906	4	11.8S	53.0E	60.3	312.5	N/A	45	-5	15	N/A
88031918	5	13.1S	54.4E	18.5	60.0	N/A	40	0	0	N/A
88032006	6	13.7S	55.8E	13.3	N/A	N/A	35	0	N/A	N/A
88032018	7	14.4S	56.5E	.0	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 18S

	00h	24h	48h
Average	19	N/A	N/A
# Cases	3	0	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88032706	1	15.0S	51.4E	18.9	N/A	N/A	35	5	N/A	N/A
88032718	2	15.8S	50.4E	26.6	N/A	N/A	35	0	N/A	N/A
88032806	3	16.5S	49.5E	13.0	N/A	N/A	30	0	N/A	N/A

Tropical Cyclone 19P

	00h	24h	48h
Average	22	117	292
# Cases	11	9	3

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88040918	1	17.7S	170.2E	68.2	260.9	468.0	45	-10	-20	0
88041006	2	18.1S	170.5E	18.0	133.9	N/A	50	-5	-5	N/A
88041018	3	17.9S	170.8E	13.3	N/A	N/A	55	-15	N/A	N/A
88041106	4	17.7S	170.6E	24.7	N/A	N/A	60	-20	N/A	N/A
88041118	5	18.0S	170.6E	41.4	136.2	N/A	65	-25	-35	N/A
88041206	6	18.2S	170.8E	.0	85.1	178.4	70	-10	20	10
88041218	7	19.1S	171.4E	.0	64.1	N/A	65	-15	-25	N/A
88041306	8	20.0S	171.8E	37.6	131.2	N/A	60	-10	-25	N/A
88041318	9	21.0S	172.2E	8.2	39.6	N/A	60	-15	-25	N/A

88041406	10	22.0S	172.6E	12.0	136.0	229.6	60	-15	-10	-10
88041418	11	23.6S	173.1E	18.8	72.0	N/A	55	-15	-15	N/A

Tropical Cyclone 20S

	00h	24h	48h
Average	18	139	277
# Cases	3	1	1

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88050918	1	15.0S	64.6E	24.7	139.1	276.5	40	-5	5	5
88051006	2	15.2S	64.9E	13.0	N/A	N/A	35	5	N/A	N/A
88051018	3	15.3S	65.5E	16.7	N/A	N/A	35	-5	N/A	N/A

Tropical Cyclone 21S

	00h	24h	48h
Average	32	207	N/A
# Cases	4	2	0

DTG	W#	BT LAT	BT LON	POS ER	24 ER	48 ER	BT WN	WW ER	24 WE	48 WE
88051900	1	12.7S	96.5E	42.9	193.0	N/A	35	-5	15	N/A
88051912	2	16.0S	97.9E	36.6	221.1	N/A	35	0	20	N/A
88052000	3	19.2S	101.1E	16.5	N/A	N/A	30	0	N/A	N/A
88052012	4	22.9S	105.0E	34.3	N/A	N/A	25	5	N/A	N/A

APPENDIX I
DEFINITIONS

BEST TRACK - A subjectively smoothed path, versus a precise and very erratic fix-to-fix path, used to represent tropical cyclone movement.

CENTER - The vertical axis or core of a tropical cyclone. Usually determined by cloud vorticity patterns, wind and/or pressure distribution.

EPHEMERIS - Position of a body (satellite) in space as a function of time; used for gridding satellite imagery. Since ephemeris gridding is based solely on the predicted position of the satellite, it is susceptible to errors from vehicle wobble, orbital eccentricity and the oblateness of the Earth.

EXPLOSIVE DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 2.5 mb/hr for 12 hours or 5.0 mb/hr for six hours (Holliday and Thompson, 1979).

EXTRATROPICAL - A term used in warnings and tropical summaries to indicate that a cyclone has lost its "tropical" characteristics. The term implies both poleward displacement from the tropics and the conversion of the cyclone's primary energy source from the release of latent heat of condensation to baroclinic processes. It is important to note that cyclones can become extratropical and still maintain winds of typhoon or storm force.

EYE - The central area of a tropical cyclone when it is more than half surrounded by wall cloud.

FUJIWHARA EFFECT - A binary interaction where tropical cyclones within about 750 nm (1389 km) of each other begin to rotate about one another. When tropical cyclones are within about 400 nm (741 km) of each other, they may also begin to be drawn closer to one another (Brand, 1970) (Dong and Neumann, 1983).

INTENSITY - The maximum sustained surface wind speed, typically within one degree of the center of a tropical cyclone.

MAXIMUM SUSTAINED WIND - The highest surface wind speed averaged over a one-minute period of time. (Peak gusts over water average 20 to 25 percent higher than sustained winds.)

RAPID DEEPENING - A decrease in the minimum sea-level pressure of a tropical cyclone of 1.25 mb/hr for 24-hours (Holliday and Thompson, 1979).

RECURVATURE - The turning of a tropical cyclone from an initial path toward the west and poleward to east and poleward.

SIGNIFICANT TROPICAL CYCLONE - A tropical cyclone becomes "significant" with the issuance of the first numbered warning by the responsible warning agency.

SIZE - The areal extent of a tropical cyclone, usually measured radially outward from the center to the outermost closed isobar.

STRENGTH - The average wind speed of the surrounding low-level wind flow, usually measured within one to three degrees of the center of a tropical cyclone.

SUBTROPICAL CYCLONE - a low pressure system that forms over the ocean in the subtropics and has some characteristics of a tropical circulation, but not a central dense overcast. Although of upper cold low or low-level baroclinic origins, the system can transition to a tropical cyclone.

SUPER TYPHOON - A typhoon with maximum sustained surface winds of 130 kt (67 m/sec) or greater.

TROPICAL CYCLONE - A non-frontal, migratory low-pressure system, usually of synoptic scale, originating over tropical or subtropical waters and having a definite organized circulation.

TROPICAL DEPRESSION - A tropical cyclone with maximum sustained surface winds of 33 kt (17 m/sec) or less.

TROPICAL DISTURBANCE - A discrete system of apparently organized convection, generally 100 to 300 nm (185 to 556 km) in diameter, originating in the tropics or subtropics, having a non-frontal, migratory character and having maintained its identity for 12- to 24-hours. It may or may not be associated with a detectable perturbation of the wind field. It is the basic generic designation which, in successive stages of development, may be classified as a Tropical Depression, Tropical Storm, Typhoon or Super Typhoon.

TROPICAL STORM - A tropical cyclone with maximum sustained surface winds in the range of 34 to 63 kt (17 to 32 m/sec) inclusive.

TROPICAL UPPER-TROPOSPHERIC TROUGH (TUTT) - A dominant climatological system and a daily upper-level synoptic feature of the summer season, over the tropical North Atlantic, North Pacific and South Pacific Oceans (Sadler, 1979).

TYPHOON (HURRICANE) - A tropical cyclone with maximum sustained surface winds of 64 to 129 kt (33 to 66 m/sec). West of 180 degrees longitude they are called typhoons and east of 180 degrees longitude hurricanes.

WALL CLOUD - An organized band of cumuliform clouds that immediately surrounds the central area of a tropical cyclone. The wall cloud may entirely enclose or partially surround the center.

APPENDIX II

NAMES FOR TROPICAL CYCLONES

Column 1	Column 2	Column 3	Column 4
ANDY	ABBY	ALEX	AGNES
BRENDA	BEN	BETTY	BILL
CECIL	CARMEN	CARY	CLARA
DOT	DOM	DINAH	DOYLE
ELLIS	ELLEN	ED	ELSIE
FAYE	FORREST	FREDA	FABIAN
GORDON	GEORGIA	GERALD	GAY
HOPE	HERBERT	HOLLY	HAL
IRVING	IDA	IAN	IRMA
JUDY	JOE	JUNE	JEFF
KEN	KIM	KELLY	KIT
LOLA	LEX	LYNN	LEE
MAC	MARGE	MAURY	MAMIE
NANCY	NORRIS	NINA	NELSON
OWEN	ORCHID	OGDEN	ODESSA
PEGGY	PERCY	PHYLLIS	PAT
ROGER	RUTH	ROY	RUBY
SARAH	SPERRY	SUSAN	SKIP
TIP	THELMA	THAD	TESS
VERA	VERNON	VANESSA	VAL
WAYNE	WYNNE	WARREN	WINONA

NOTE: Names are assigned in rotation and alphabetically. When the last name in Column 4 (WINONA) has been used, the sequence will begin again with the first name in Column 1 (ANDY).

SOURCE: CINCPACINST 3140.1S

APPENDIX III

REFERENCES

Allen, R. L., 1984: COSMOS: CYCLOPS Objective Steering Model Output Statistics. Postprints, 15th Conference on Hurricanes and Tropical Meteorology. Miami, Fl., January 9-13, 1984, pp. 14-20.

Atkinson, G. D., and C. R. Holliday, 1977: Tropical Cyclone Minimum Sea-Level Pressure and Maximum Sustained Wind Relationship for theWestern North Pacific. Monthly Weather Review, Vol. 105, No. 4, pp. 421-427 (also FLEWEACEN TECH NOTE: JTWC 75-1).

Bao, C., 1981: Forecasting Typhoon Movement Based on Satellist Cloud Maps. Report UHMET 81-03, University of Hawaii, 26 pp.

Brand, S., 1970: Interaction of Binary Tropical Cyclones of the Western North Pacific Ocean. Journal of Applied Meteorology , Vol. 9, pp. 433-441.

Chen, L., and W. M. Gray, 1985: Global View of the Upper-Level Outflow Patterns Associated with Tropical Cyclone Intensity Change During FGGE. Atmospheric Science Paper 392, NASA NAG 5-299, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 106 pp.

Diercks, J. M., R. C. Weir and M. K. Kopper, 1982: Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1980 through June 1982). NAVOCEANCOMCEN/JTWC TECH NOTE 82-1, 77 pp.

Dong, K., and C. J. Neumann, 1983: On the Relative Motion of Binary Tropical Cyclones. Monthly Weather Review, Vol. 111, pp. 945-953.

Dunnavan, G. M., 1981: Forecasting Intense Tropical Cyclones Using 700 mb Equivalent Potential Temperature and Central Sea-Level Pressure. NAVOCEANCOMCEN/JTWC TECH NOTE 81-1, 12 pp.

Dvorak, V. F., 1984: Tropical Cyclone Intensity Analysis Using Satellite Data. NOAA Technical Report NESDIS 11, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Earth Satellite Service, Washington, D. C., 20233, 46 pp.

Gray, W. M., 1979: Tropical Cyclone Origin, Movement and Intensity Characteristics Based on Data Compositing Techniques. NAVENVPREDRSCHFAC Contractor Report CR 79-06, 124 pp.

Herbert, P. H. and Poteat, K. O., 1975: A Satellite Classification Technique for Subtropical Cyclones. NOAA Technical Memorandum NWS SR-83, 25 pp.

Hodur, R. M. and S. D. Burk, 1978: The Fleet Numerical Weather Central Tropical Cyclone Model: Comparison of Cyclonic and One-Way Interactive Boundary Conditions. Monthly Weather Review, Vol. 106, pp. 1665-1671.

Holland, G. R., 1980: An Analytical Model of Wind and Pressure Profiles in Hurricanes. Monthly Weather Review, Vol. 108, No. 8, pp. 1212-1218.

Holland, G. R., 1983: Tropical Cyclone Motion; Environmental Interaction, plus a Beta Effect. Journal of Atmospheric Science, Vol. 40, pp. 328-342.

Holliday, C. R. and A. H. Thompson, 1979: Climatological Characteristics of Rapidly Intensifying Typhoons. Monthly Weather Review, Vol. 107, pp. 1022-1034.

Hovmöller, E., 1949: The Trough-and-Ridge Diagrams. Tellus, Vol. 1, pp. 62-66.

Huntley, J. E., 1980: Tropical Cyclone Wind Radius Program. Annual Tropical Cyclone Report, 1980, p121.

Matsumoto, C. R., 1984: A Statistical Method for One to Three Day Tropical Cyclone Track Prediction. Atmospheric Science Paper 379, NEPRF N00014-83-K-002, NSF ATM-8214041, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 201 pp.

Renard, R. J., 1968: Forecasting the Motion of Tropical Cyclones Using a Numerically Derived Steering Current and its Bias. Monthly Weather Review, Vol. 96, No. 7, pp. 453-469.

Renard, R. J., S. G. Calgon, M. J. Daley and S. K. Rinard, 1973: Forecasting the Motion of North Atlantic Tropical Cyclones by the MOHATT Scheme. Monthly Weather Review, Vol. 101, No. 3, pp. 206-214.

Sadler, J. C., 1979: Tropical Cyclone Initiation by the Upper-Tropospheric Trough. Naval Environmental Prediction Research Facility Technical Paper No. 2-76, 103 pp.

Sadler, J. C., M. A. Lander, A. M. Hori and L. K. Oda, 1987: Tropical Marine Climatic Atlas, Volume II Pacific Ocean. University of Hawaii Report No. UHMET 87-02, 27 pp.

Sikora, C. R., 1976: A Reevaluation of the Changes in Speed and Intensity of Tropical Cyclones Crossing the Philippines, FLEWEACEN TECH NOTE: JTWC 76-2, 11 pp.

Tsui, T. L., 1984: A Selection Technique for Tropical Cyclone Objective Forecast Aids. Postprints, AMS 15th Conference on Hurricane and Tropical Meteorology, Miami, Fla., pp 40-44.

Tsui, T. L. and R. J. Miller, 1986: Evaluation of JTWC Tropical Cyclone Objective Forecast Aids (1978-85). Naval Environmental Prediction Research Facility Technical Report, TR 86-05, 44 pp.

Weatherford, C. L., 1985: Typhoon Structure Variability. Atmospheric Science Paper No. 391, NSF/NOAA-ATM 8419116, Department of Atmospheric Science, Colorado State University, Fort Collins, Colo., 77 pp.

Weir, R. C., 1982: Predicting the Acceleration of Northward-moving Tropical Cyclones using Upper-Tropospheric Winds. NAVOCEANCOMCEN/JTWC TECH NOTE 82-2, 40 pp.

Wirfel, W. P. and S. A. Sandgathe, 1986: Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1982 through June 1984). NAVOCEANCOMCEN/JTWC TECH NOTE 86-1, 102 pp.

APPENDIX IV

PAST ANNUAL TROPICAL CYCLONE REPORTS

Copies of the past
Annual Tropical Cyclone Reports
can be obtained through:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Refer to the following acquisition numbers when ordering:

YEAR	ACQUISITION NUMBER
1959	AD 786147
1960	AD 786148
1961	AD 786149
1962	AD 786128
1963	AD 786208
1964	AD 786209
1965	AD 786210
1966	AD 785891
1967	AD 785344
1968	AD 785251
1969	AD 785178
1970	AD 785252
1971	AD 768333
1972	AD 768334
1973	AD 777093
1974	AD 010271
1975	AD A023601
1976	AD A038484
1977	AD A055512
1978	AD A070904
1979	AD A082071
1980	AD A094668
1981	AD A112002
1982	AD A124860
1983	AD A137836
1984	AD A153395
1985	AD A168284
1986	AD A184082
1987	AD A191883

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT AS IT APPEARS IN THE REPORT/ DISTRIBUTION UNLIMITED
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION NAVOCEANCOMCEN/JTWC 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION NAVOCEANCOMCEN/JTWC
6c. ADDRESS (City, State, and ZIP Code) COMNAVMAR BOX 17 F.P.O. SAN FRANCISCO, CA 96630	7b. ADDRESS (City, State, and ZIP Code) COMNAVMAR BOX 17 F.P.O. SAN FRANCISCO, CA 96630
8a. NAME OF FUNDING/SPONSORING ORGANIZATION NAVOCEANCOMCEN/JTWC 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) COMNAVMAR BOX 17 F.P.O. SAN FRANCISCO, CA 96630	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
1988 ANNUAL TROPICAL CYCLONE REPORT

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
ANNUAL	FROM JAN 88 TO DEC 88	1988	216 PLUS i-x

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	TROPICAL CYCLONES; TROPICAL STORMS; TROPICAL DEPRESSIONS; TYPHOONS/SUPER TYPHOONS; TROPICAL CYCLONE RESEARCH; METEOROLOGICAL SATELLITE
04	02		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

ANNUAL PUBLICATION SUMMARIZING TROPICAL CYCLONE ACTIVITY IN THE WESTERN NORTH PACIFIC, BAY OF BENGAL, ARABIAN SEA, WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS. A BEST TRACK IS PROVIDED FOR EACH SIGNIFICANT TROPICAL CYCLONE. A BRIEF NARRATIVE IS GIVEN FOR ALL TYPHOONS AND SELECTED TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS. ALL RECONNAISSANCE DATA USED TO CONSTRUCT THE BEST TRACKS ARE PROVIDED, UPON REQUEST, ON FLOPPY DISKETTES. FORECAST VERIFICATION DATA AND STATISTICS FOR THE JOINT TYPHOON WARNING CENTER (JTWC) ARE SUBMITTED.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL FRANK H. WELLS	22b. TELEPHONE (Include Area Code) 671-344-5240	22c. OFFICE SYMBOL NOCC/JTWC

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

BLOCK 18 (CONTINUED)

TROPICAL CYCLONE INTENSITY
TROPICAL CYCLONE BEST TRACK DATA
TROPICAL CYCLONE FORECASTING
TROPICAL CYCLONE RECONNAISSANCE
DYNAMIC TROPICAL CYCLONE MODEL
TYPHOON ANALOG MODEL
TROPICAL CYCLONE STEERING MODEL
CLIMATOLOGY/PERSISTENCE TECHNIQUES
TROPICAL CYCLONE FIX DATA
DRIFTING BUOYS